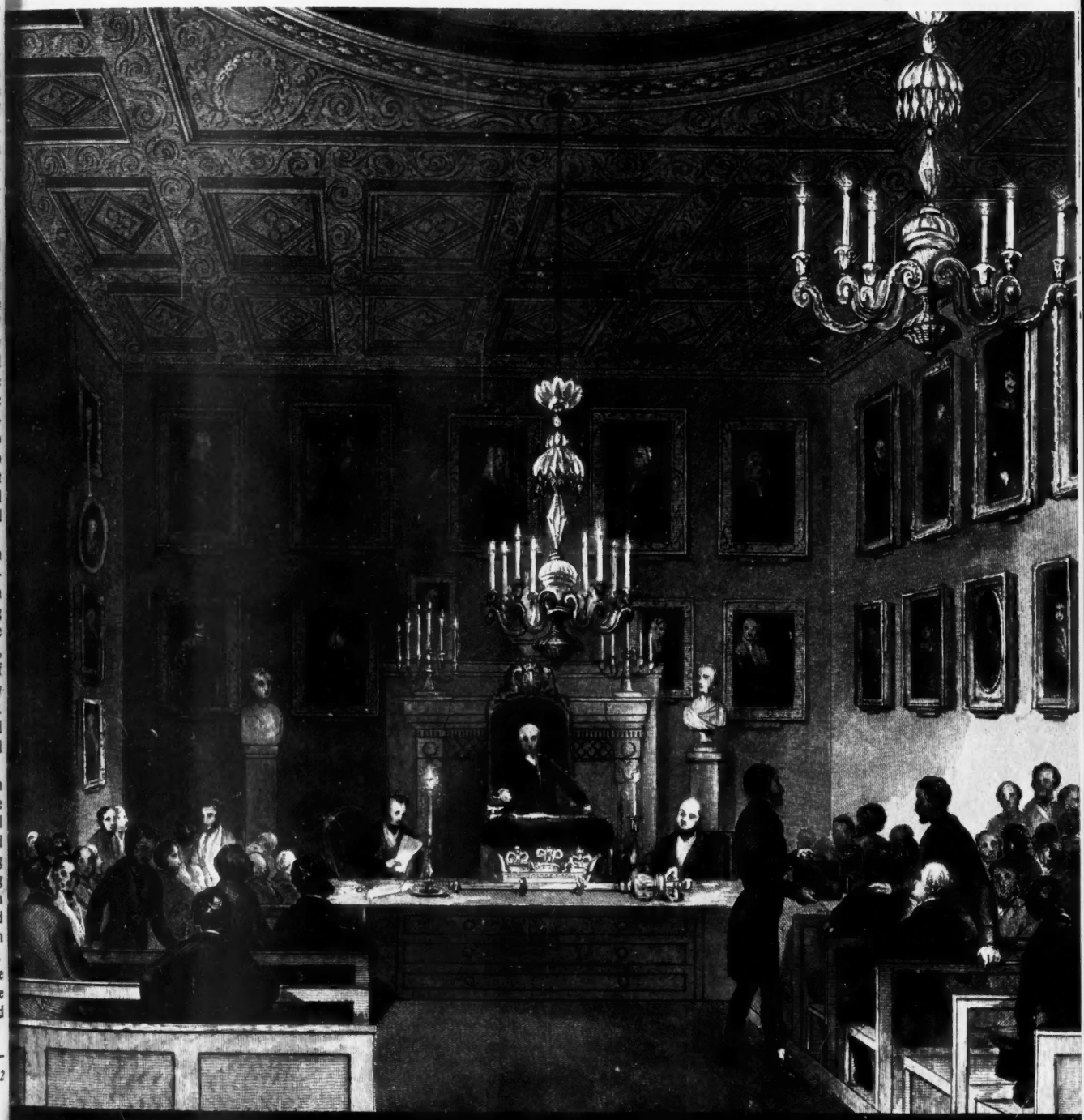
DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

JULY 1960 3/-



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Editor
Anthony R. Michaelis, PH.D., B.SC.

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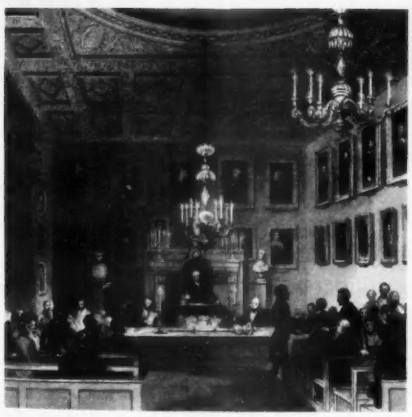

A MEETING OF THE ROYAL SOCIETY AT SOMERSET HOUSE

Starting with the top row of portraits from the left behind the President, the second portrait appears to be of Humphry Davy, and the fifth is probably of James Bradley. In the second row the first portrait is probably of Francis Bacon, and the fourth portrait which is partly hidden by the chandelier on the mantelpiece might be of Banks. The bust on the right is probably of Newton. The Officers sitting at the desk are, on the left reading a paper, Edward Sabine, Secretary; Davies Gilbert, President; and on the right probably P. M. Roget, Secretary.

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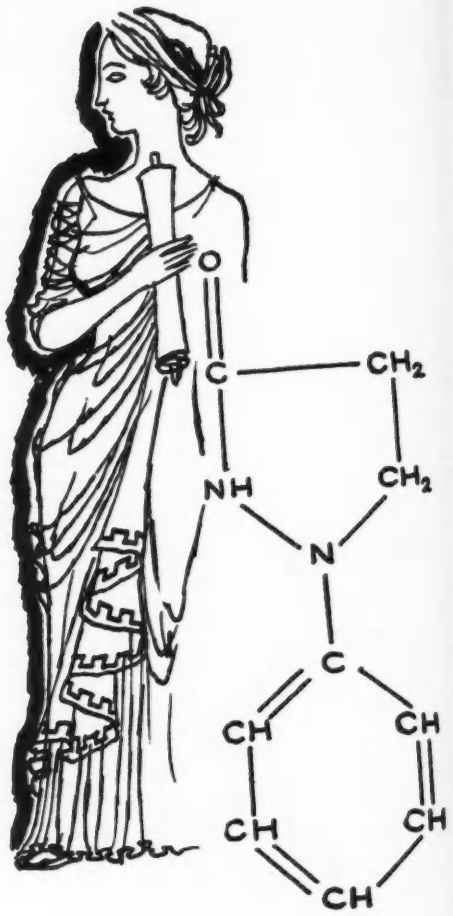
Art by the grace of Science



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THE PROGRESS OF SCIENCE

A STRATEGY FOR SOCIAL RESEARCH

That the postwar years have been an era of unprecedented scientific advance may at first sight seem a truism. What is less obvious and of significance is why this is so: the reason is not far to seek. In modern society, whatever the political coloration, not only are individual scientists securing major advances, but these are beginning to take place, unlike in previous eras, within a planned and institutionalised framework. Since scientific resources are limited, there must, as we have so often urged in these columns, be a science of sciences.

If this is true of the physical sciences, how much truer must it be of the social sciences. Their importance in the modern world is unquestioned: for just as the scientific method is essential for the study of physical phenomena, so too is it an essential tool in the study of an ever-widening range of human problems. If scientific progress benefits from an institutionalised framework, then this also holds good for the social sciences. For, alas, not only are the resources available for social research limited, but society —the natural field for social research—is continuously changing and its effective study demands a collective focus. In every society, whatever its ideology, men will consciously try to shape their collective future by power of reason, that is, they will plan. But planning is no intuitive exercise: it can only be beneficial if the rules by which society operates and the consequences of particular courses of action are explored in a scientific spirit.

Ideally, it may be argued, social research should be directed and encouraged on an international level: in actual fact, this is still only possible to a limited degree. Indeed, since social sciences deal primarily with single communities, the manner of their deployment is best considered on a national level; yet it is of course true that this is an important field for international co-operation. That UNESCO in particular has, in its short lifetime, great achievements to its credit, that it is assisted by international associations for the most important social-science disciplines, are facts which should not be overlooked. Nevertheless, for many reasons, not least the financial and the administrative, there is a limit to what these can accomplish. The possibilities of synthesising social research seem rather greater at the European level, but even here different institutional frameworks and different stages of social progress impose a not insignificant barrier.

Consequently, we in DISCOVERY are directing our main attention to the place of social research in Britain today. Is its usefulness fully recognised? Are social research and industry on speaking terms? Has the gap between the exact and the social sciences been reduced? Is its significance in the administrative process appreciated? Is it properly endowed? Is it rationally deployed? Is an adequate *cadre* of the country's trained manpower versed in the social-science disciplines? Are arrangements for the dissemination of the results of research flexible and effective? While we would recognise the great advance in the national position of our social sciences during the postwar years, these issues must remain matters for continuous and searching inquiry. For while it would be quite wrong to deny that there has been an advance—and doubtless a major one in the volume of research—two related factors still cause concern. First, the fact that we do not know what the nation is spending on social research: second, that there is no co-ordinating body for the social sciences, either within or without the Government machine, as there is in many countries. While the fear has been expressed that such a body would lead to "the premature crystallisation of spurious orthodoxies", the fact that we lack a proper Social Science Research Council is bound, whatever the degree of co-ordination by other means, to be a weakening factor.

Then again, the resulting absence of central co-ordination is to be felt in many spheres and disciplines. We can only give a few examples. Important questions are left unanswered in the manpower field. How many, and what type of social scientists should our universities aim to produce? How many will actually find employment in the social sciences, and how many should receive such training as part of their background? These are questions which form the subject of official study so far as scientific manpower is concerned, but are inadequately treated for the social sciences.

Next, mention must be made of a further major area, the social security field, where there seems to be a critical absence of central policy-making. Unquestionably, much research is done, for instance into geriatrics, family structure, poverty, and so forth; nevertheless, in the social policy field it is within our existing arrangements inevitable that we should move from one *ad hoc* crisis to another. The possibility of enlisting operational research techniques to study our social problems and services, and to feed conclusions in through a central policy-making secretariat have often been recognised, but unhappily not adequately acted upon. That the expertise for effective social policy-making exists, or could exist, is unquestionable. Our social statistics, despite certain lacunae, are extensive and still growing. The State has in the Government Social Survey an operational sociological research unit which can enable it to choose between alternative priorities and policies, and which should be financed more generously. This is not the problem: it is that the machinery for research co-ordination and central policy-making is weak. The position is analogous in the area of social research for industry. Valuable *ad hoc* research (though exactly how much we do not know) is being undertaken for industry, but the need is increasingly apparent to relate this within some broader conceptual framework of long-range development. Who is to do this work, and who is to pay for it? It certainly cannot come out of the £53,000 of the DSIR's Human Sciences Committee's first programme. And yet there is an undoubted need for fundamental as opposed to applied social research in this field, for to quote a recent publication of the European Productivity Agency. "there is an increasing awareness . . . that productivity is not simply a matter of technical 'know-how', and that it is also, if not primarily a political and social 'invention'—the outcome of certain political and social conditions and values". For the study of such vital problems, a strategy for social research is indeed urgent.

POUNDS, SHILLINGS, AND CENTS

From time to time the British people become temporarily aware of the irrationality of their communication habits, and begin to think that something ought to be done to straighten them out. After the war there was a wave of interest in spelling reform. In 1951 we were thinking about our weights and measures. Now it is the coinage. These spells of enthusiasm seldom last very long and never yet have had any effect (unless one counts to their credit the fact that the metric system has been adopted by scientists and by the pharmaceutical industry). It may sound like foolish optimism, but it is very tempting to believe that this time will be different. The case for reform of the coinage is becoming steadily stronger and the opposition seems to be weakening.

In 1957 a decimal coinage was introduced by India. South Africa is making the change during 1961–2. In Australia, New Zealand, and Rhodesia, official commissions of inquiry are about to report or have reported. Even the West Indies, probably the only part of the Commonwealth more conservative than Britain, is changing to the BWI dollar. If things go on at this rate and we do nothing, by 1970 we may expect to stand in magnificent isolation as the only country in the world without a decimal coinage. At this point, surely, doubts as to whether it is ourselves or everyone else who is out of step must at last begin to worry us.

It seems almost certain that we shall make the change ultimately, and this is indeed one of the strongest arguments for making it now, for the cost of the changeover is not a fixed proportion of the national income but a proportion which rises the richer we become. India was able to make the change at negligible cost, but the economy of a highly industrialised country such as Britain is such a complex structure that a change in one of the fundamental elements out of which it is built is a formidable task.

For example, the recent British Association committee* obtained evidence suggesting at least £128 million as the cost of converting, or replacing, existing machinery such as cash registers and accounting machines. This in itself is an alarming sum; but the mechanisation of accounting and office work is certain to expand rapidly in the coming decade and it might well be that the cost of conversion of the machinery which will be installed ten years from now would be twice as great. Thus, as the Committee insist, the problem is an urgent one.

Machine conversion is, of course, only one among many costs. Conversion of documents may well prove even more expensive. For example, there are 100 million industrial assurance policies in force, the sums assured being expressed in pounds and shillings and the premiums (usually weekly) in pence or shillings and pence. Over 5 million policies have weekly premiums of 1*d.* or 2*d.* Although the Committee did not attempt to estimate the total cost of introducing a decimal coinage it said enough to imply that £300–£400 million may well be an underestimate.

On the other hand the advantages, of course, persist for all time, and include the saving in time in the educational syllabus, which can hardly be evaluated.

On one point the Committee have been led astray by their decision to base their recommendations on the opinions expressed by the business world. The respondents to their questionnaire expressed a marked preference for retaining the £ (64% in favour), and adjusting the other units accordingly. The argument for this is essentially one of prestige: the £ is internationally known and respected, and is the largest unit of currency in the world. This argument imputes a remarkable naïveté to foreign business men; one suspects that the only people with this strong irrational attachment to the £ are in fact British business men who are putting their own sentiments into the mouth of the foreigner.

There are three arguments in favour of a unit valued at 10*s.* None of them is overwhelming, but together they make a stronger case than the sentimental argument for the £.

First, South Africa has adopted a 10*s.* unit and Rhodesia, New Zealand, and Australia are likely to do so. Assuming these countries make their decision before us, we should be causing unnecessary inconvenience by not falling in with them.

Secondly, the 10*s.* unit retains the shilling, which is far more commonly used as a unit by the general public than the £ (indeed sums up to £5 are often quoted in shillings). This is important because when coinage systems are rationalised the public tends to stick to the old system unless the new system is made very easy. One still hears "cent sous" in France for 5 francs, and we ourselves say "half a crown" as readily as "two and sixpence". Such habits are remarkably persistent. Now if the £ were retained, articles worth at present 3*s.* *or* 5*s.*, for example, will not for many decades be quoted as 1 florin 50, or 2 florins 50; people will still say three shillings and five shillings, and the advantage of the decimal system will be lost. On the other hand, if the 10*s.* unit is adopted, the only unit to be suppressed is the £, and this is already in very little use for everyday transactions.

The third argument will be unpopular and may appear almost treasonable to some; it is hardly the kind of argument that a politician can mention but it is nevertheless worth some consideration. The 10*s.* unit is not so very much larger than the U.S. dollar, and it is not so very unlikely that at some time in the next fifty years the £ will have to be deflated again with respect to the dollar. If the currency of the British Commonwealth were brought into parity with the dollar, a very large step would have been taken towards the creation of a world currency. It seems permissible to pave the way for this *possibility* by taking the appropriate decision now when our currency is under review.

The Committee came down firmly in favour of decimalisation, and an overwhelming proportion of the companies, trade associations, and chambers of commerce which returned an opinion were in favour. The only substantial opposition came from government departments, particularly the Post Office. However, the Government is believed to be sympathetic, and a Board of Trade Committee in 1951 favoured decimalisation. *The Times* expressed its approval on May 4. There seems to be a real possibility of action.

* "Decimal Coinage and the Metric System—Should Britain Change?" Joint report of the British Association for the Advancement of Science and the Association of British Chambers of Commerce (Butterworths, 1960, 107 pp., 7*s.* 6*d.*).

OBSERVATION VERSUS EXPERIMENT

The cancer and smoking controversy is still not settled. Sir Ronald Fisher has recently been on the warpath again with the publication of a collection of his papers in defence of tobacco.* Sir Ronald argues that the evidence that smoking causes cancer is ambiguous and suggests that the two may have a common genetic cause.

The controversy raises fundamental issues on the nature and limits of scientific inference which are worth the attention of every scientist. If an association is observed between variables x and y then, as we all know, the explanation may be that x causes y, that y causes x, or that both x and y are caused by z. Any of these causal links may be direct, or may operate through intervening variables. How do we distinguish between the three explanations? As long as we are limited to observation we cannot make a complete distinction. We can indeed argue that causes precede effects, and this usually suffices to distinguish "x causes y" from "y causes x", but it can never rule out the third possibility (at any rate, so long as z is unknown). By further observation we may, of course, eliminate every proposed z in turn, but however often we do this the sceptic can always point to some other z which we have not yet examined. The process is endless, and rigorous evidence can never come this way. These are the limitations of the observational method.

But as soon as we turn from observation to experiment the matter can be settled at once. We have only to vary x deliberately, in some mechanical (and preferably random) way, such as throwing dice or using the digits of π, and we know that x is then not being caused, directly or indirectly, by any z, since we know how it *is* being caused. If when we do this we find y still varying with x, then x is the cause of y; if we do not, then one of the other explanations is true. In the latter event we go on to vary y randomly, and the resulting behaviour of x distinguishes between the remaining hypotheses.

This is one of the two reasons why experiment is so much more powerful than observation, the second reason being that experiment allows us to produce events which are so rare that they virtually never present themselves for observation in the natural world. (We could observe the natural world till doomsday and never see a drop of concentrated sulphuric acid meet a piece of zinc.) It is interesting that the first of these reasons is crucial to the biosciences, but also trivial in physics and chemistry where the second assumes overwhelmingly greater significance. And this seems to be because in biology, medicine, and agriculture we are usually trying to make commoner or rarer some type of event which is normally quite frequent, while in physics and chemistry we tend to be interested in conditions which are virtually unobservable outside a laboratory.

But, it may be argued, is not all this talk of cause and effect outmoded? Has not quantum mechanics shown that the world is indeterministic? Is not cause and effect part of the 19th century ether-and-billiard-balls view of the world, and does not strict scientific objectivity demand that we limit ourselves to the only thing we actually know, namely that certain events tend to go together and certain others do not? This point of view is nonsense, and demonstrably so. It would, indeed, be dangerous nonsense if scientists really believed it, but fortunately it is one of those week-end beliefs which are left outside when the scientist enters his laboratory. For when he switches on the current and the experiment starts he never doubts for a moment that it was he who started it, and that if he had not switched on it would not have started. Yet this is what cause and effect means.

Science produces two kinds of statement: (1) A tends to go with B, (2) if you make A happen then B will tend to happen. These types of statement come from observation and experiment respectively (except, of course, when they come from reasoning, which is also very common). It is the second kind of statement that is causal in character, and it means no more than "A causes B" (either directly or through an intervening variable). The concept of cause, then, is intimately bound up with the idea of *control*. If we wish successfully to control things, we require propositions about causes; and conversely, by trying to control things and noting our success and failure (that is, by experiment) we *reach* propositions about causes. If we are limited to observation, we have no basis for control.

What happens if we wish, for pressing social reasons, to take a decision involving the control of a phenomenon when we have nothing but observational data? What happens is—bitter controversy, because there is no rigorous and accepted canon for reasoning from correlation to causation. Yet at the same time it is wrong to think, as some people do, that in such a situation we are committed by our scientific principles to a policy of inaction. The trouble is that, although we have no rigorous canon, there is nevertheless *something* to be said.

Let us take two examples, one at each extreme. The first is often quoted. The statistician Udny Yule discovered that if one compared the number of apples imported into Great Britain in a year and the number of divorces in the year one found an unquestionably significant and positive correlation. Nevertheless, few scientists would be tempted to suppose that one of these factors caused the other. But here is a second example. Observation shows that thunder usually follows lightning. No spark approaching the magnitude of lightning has ever been produced experimentally, yet no scientist doubts that lightning causes thunder. Why is it that, where there is nothing but observational evidence, in one of these cases we are quite certain that there is not a direct causal connexion and in the other equally certain that there is. Are these conclusions, about which we should all agree, merely the prejudices of the scientists or are they justifiable scientific inferences? It is obvious that they are based on some general views of the way things work. We have a knowledge of human psychology which tells us that consumption of apples is not the kind of thing that affects marital happiness, nor vice versa. On the other hand, electric sparks emit noises, and there is no reason to doubt that large sparks would emit large noises. And if it is not the spark, what else is it that makes the thunder? These arguments, though we all accept them, are distressingly vague, and if we should happen to meet someone who

* "Smoking: The Cancer Controversy," by Sir Ronald A. Fisher. Oliver & Boyd.

disagrees with them there is not much that we could do except shout a little louder.

It is much the same with smoking and lung cancer. Most people feel that the suggestion of a direct causal connexion is plausible. Prof. Fisher's alternative theory, that smoking and lung cancer have a common genetic cause, is not easy to swallow. Even the broadest characters of human behaviour (excepting the clearly pathological) have never been shown to have more than a very limited genetic component in their aetiology, and most psychologists have come to take it for granted that the highly specific habits which differentiate normal individuals are almost entirely determined by environment. They could, of course, be wrong, and some of the subsidiary findings about smoking and cancer do not comfortably fit the official view, while some recent findings by Eysenck and his co-workers* suggest that there is at least some correlation between the habit of smoking and certain broad personality characteristics. Sir Ronald Fisher is right in clamouring for research into these anomalies.

But meanwhile people are smoking and people are dying, and there is some suggestive evidence linking the two. Nobody denies that the Government could act to some effect if it wished. Sir Ronald's mistake is surely in supposing that inaction requires much less justification than action.

WILLIAM OUGHTRED (1574–1660)

One of the foremost mathematicians of his day, William Oughtred died on June 30, 1660. Tradition has it that his death was caused by joy at hearing of the restoration of King Charles II to the throne, but as the King made his triumphal return to England on May 26, 1660, it is evident that Oughtred did not succumb suddenly, though the excitement of recent events may have hastened his end.

Born at Eton on March 5, 1574, Oughtred was educated at King's College, Cambridge, and while still an undergraduate wrote his "Easy Method of Geometrical Dialling", a work which was so esteemed by Christopher Wren that he prepared a Latin translation which was published in 1648. Oughtred was elected a Fellow of his College in 1595, and in 1605, two years after he had been ordained priest, was given the living of Shalford, in Surrey. In 1610 he became rector of Albury, near Guildford, where he spent the greater part of his life quietly following his scientific interests. Among his pupils was Seth Ward (1617–89), successively Bishop of Exeter and of Salisbury, and a celebrated Savilian professor of astronomy at Oxford.

Oughtred's invention of the slide-rule in 1622 was an advance of practical importance, for his introduction of two logarithmic scales sliding over one another was a great deal less cumbersome than the single scale inaugurated by Edmund Gunter (1581–1626) in 1620, and which had necessitated the use of a pair of compasses for the purposes of multiplication. The idea of a projected horizontal instrument for delineating dials upon any kind of plane came to Oughtred about 1600, and this also made for simplicity as it could be used for all the work done by a globe. One of Oughtred's former pupils, William Foster, published an account of this instrument in 1633.

In 1631 Oughtred published his "Clavis Mathematicae", a work which was extolled by Robert Boyle who, writing to a friend in 1647, mentioned his intention of "Englishing" it, declaring that it "doth much content me", and that it afforded "a much more instructive way of logic than that of Aristotle". The "Clavis" was a good textbook of algebra and arithmetic, and is of special interest because within its pages the author introduced the well-known symbols × for multiplication, and :: for in proportion. He also wrote a treatise on navigation entitled "Circles of Proportion", 1632, and in a letter dated 1645 he demonstrated the futility of all attempts to prove the equality of any given square or circle. In his "Budget of Paradoxes", 1872, the eminent mathematician, Augustus DeMorgan (1806–71), credited Oughtred with the invention of trigonometrical abbreviations.

Although he was not a man of action, Oughtred had strong royalist leanings which sometimes seemed likely to involve him in trouble with those of opposite political views. The fact that he was able to pursue his scholarly mode of life with but little interruption was due in great measure to the high esteem in which he was held by many of the great men of his day. Isaac Newton called him "that very good and judicious man". and the antiquary John Aubrey, whose pen-pictures of his contemporaries provide so many lively and amusing biographical details, left this account of him: He was, said Aubrey, "a little man, had black hair and black eyes, with a great deal of spirit. His wit was always working." His description of the mathematician was based in part on information supplied by a son, and included such homely details as the fact that he "did use to lye a bed till eleven or twelve o'clock with his doublet on. . . . Studied late at night . . . had his tinder-box by him; and on the top of his bed-staffe he had his inkhorn fixt." We are told also that he slept but little, and we can admire the enthusiasm with which he conducted his researches in conditions which we should find inconvenient and discouraging. We can also spare some sympathy for his family, perhaps, when we learn that when engaged on a problem he "would not come down to meals till he had found the quaesitum".

SCIENCE AND INDUSTRIAL RELATIONS

With strikes and other industrial disputes in the headlines, it is gratifying to discover that scientific principles are at last being applied to the complex subject of industrial relations. A London firm of management consultants has introduced what it describes as a systematic method under the general title of Industrial Motivation.

This method begins from the assumption that the behaviour of human beings is due to circumstances and is not mere caprice. It aims to study the circumstances in a factory, for example, and modify them if necessary to produce an environment conducive to good relations and, *in extenso*, to increased production and reduced waste. One method used is communication by posters, specially designed for the purpose, and displayed regularly on selected sites in the factory. These posters are designed on sound psychological principles. They stress the importance of the individual to the group and the necessity to work together

* "Smoking and Personality", *British Medical Journal*, May 14, 1960.

a customer never forgets!
GOOD WORK BRINGS REPEAT ORDERS
SATISFIED CUSTOMERS MEAN YOUR SECURITY!
ON TOP OF YOUR JOB - ON TOP OF THE WORLD

Let me tell you!
YES WE WANT YOU TO TELL US YOUR GOOD IDEAS
A SMALL IMPROVEMENT CAN MAKE A BIG DIFFERENCE TO YOU
ON TOP OF YOUR JOB - ON TOP OF THE WORLD

Teamwork!
Gets things done efficiently, cheerfully
We all depend on each other
Let's all pull our weight
TOP OF YOUR JOB - ON TOP OF THE WORLD

for the common interest of staff and management. It would seem that a public already conditioned to advertisements would find such a technique a very powerful method of communication.

The cost of a poster campaign is quite small, of the order of a penny per person per day. Experience with the technique gathered over the past year or so has been encouraging. Among the firms using the scheme is a well known manufacturer of scientific instruments who reports favourably on the experiment and considers that the relations between workers and management in the plant has shown a significant improvement since it began.

The poster campaign is now being supplemented by a series of courses for supervisors and foremen. The reasoning behind this is clear—a man needs instruction to be an efficient leader, a point that has been the basis of military training for centuries. Students are instructed in industrial economics, the objects of Industrial Motivation, and the methods used in applying it. The importance of removing causes of discontent before they develop to serious proportions is emphasised. Many strikes are obviously caused by general frustration in many cases unknown and unrecognised by the striker, and the official reason given as a cause is but a peg on which this frustration is hung. Early decisive action could often remove the cause before any deterioration of relations had taken place. Foremen are shown the importance of getting executive action as quickly as possible in such cases.

The management consultants emphasise that the whole system is one of evolution. The methods so far employed are but a stage in development of Industrial Motivation and might be considered as an initial catalyst to the final reaction. They point out that at present there are no hard and fast rules about the best methods of factory control, and that any system must be flexible to suit the given organisation and situation. The use of posters and courses are the first, and they believe, sound steps. An empirical approach, based on sound psychological foundations, will be necessary before the next steps can be perfected.

Industrial Motivation has appeared at an opportune time. All thinking people are vitally concerned by the trends in present-day relations between management and labour, if these divisions still have any real meaning—the progressive industrialist and trade unionist is well aware that this division is fast disappearing. Gone are the days when industrial units were small enough to allow a personal relationship between owner and workmen, and gone also are the days when the fear of unemployment might be a dominant factor in staff control. The size of the pay packet is also losing its incentive power and it is clear that a more scientific approach must be made. Industrial Motivation is a possible solution and one that seems well worth serious consideration. Its success or failure will depend on the flexibility with which its exponents employ it and on the use of experiment as a considered policy in the administration of personnel.

Examples of Industrial Motivation posters

One of Britain's most ambitious port mechanisation schemes is being fostered by the North of Scotland, Orkney and Shetland Shipping Co. From last Easter, over 80 million eggs will be trucked and palletised every year during shipment from Orkney and Shetland to the Scotish mainland.

PORT MECHANISATION—THE PROBLEMS AND ADVANTAGES

Today's campaign for increased mechanical handling in British ports is not concerted and is frequently misdirected. Many organisations—often with ulterior and usually unrelated motives, and all with varying viewpoints—are clamouring for greater mechanisation. Necessary for attracting greater trade, imperative with the possible coming of a European Free Trade Area, increased mechanisation can only be achieved if vested interests meet together for complete reconsideration of the difficulties and possibilities involved. All sections of the industry, meeting in harmony, must recognise what advantages increased mechanisation offers: quicker quayside working (which results in faster vessel turn-round, attracts greater trade to ports and stevedores, and increases turn-over), a cut in shipowners' running costs, and an improvement in dockers' working and financial conditions.

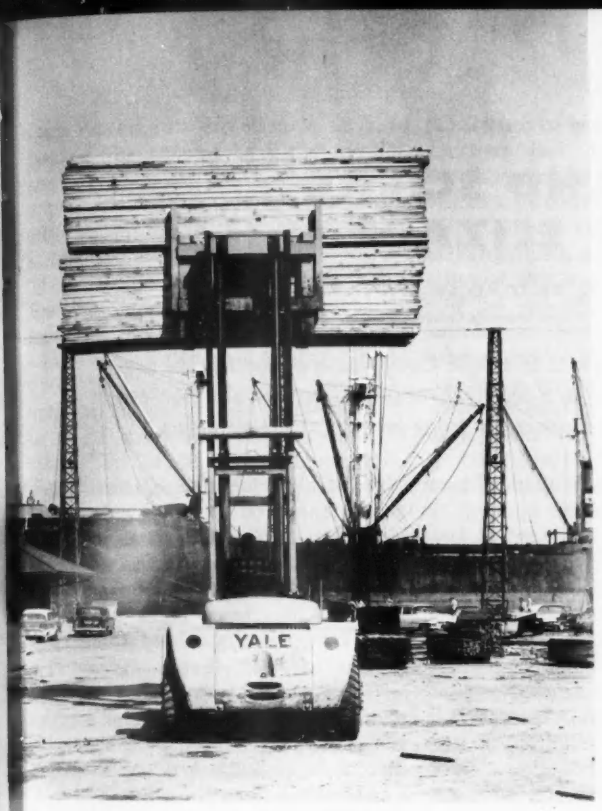
Piecemeal handling of this problem, which needs proper co-ordination, has already placed British ports far behind world competitors.

In the Great Lakes of Canada, where trucking and palletisation are well advanced, 2000 tons can be loaded in less than twelve hours: an average cargo-handling rate of 166·6 tons an hour, the total number of men in the three holds being equivalent to the size of one British gang. Current working-rates in Britain with the same gang strength would necessitate a loading-time of 333 hours for the same amount of cargo.

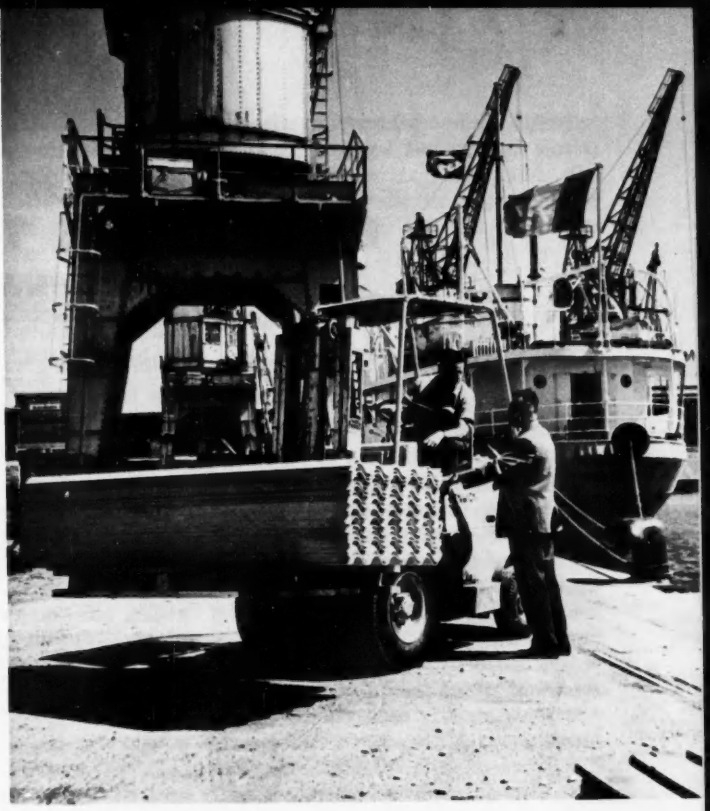
A yardstick to measure the working of a port is the tonnage of cargo worked per lineal foot. In Britain, 250 tons is the usual capacity for a port. At Singapore, use of over 200 industrial trucks and small gangs keep the figure at around 320 ft./tons. Mechanisation was made possible at Singapore by frequent labour drifts. Labour was not replaced; trucks were introduced. Gang strength was finally cut from twenty to five—with no objections from the unions.

In Britain, union leaders appear to accept mechanisation only as a supplement to the existing dock labour force. Port authorities and employers claim cuts in gang strength are the first way to justify increased mechanisation. Recently, as a result of recessions in world trade, labour surpluses at the docks are running as high as 15%—intensifying resistance among dockers to mechanisation. This surplus of dockers and existing labour relationships forbid reductions in gangs and prohibit widespread introduction of materials handling equipment.

The introduction of a pension scheme for dockers over sixty-five would immediately reduce labour numbers. By bargaining for a reduced labour force and smaller gangs in exchange for a pension scheme (long demanded by the unions) mechanisation could be speeded up. This would make for a smaller but more skilled, more highly mechanised and better-paid labour force and would thus rescue British ports from serious manpower wastages and outmoded handling methods.



Mechanisation in American ports is well advanced. Trucks of this type can be seen cutting loading times and increasing dockers' earnings.



The world's first taxi truck service at Marseilles where fork trucks are hired by stevedoring concerns.

Already, in Newcastle, use of work-saver trucks for handling palletised cargo on Scandinavian ships has increased dockers' earnings from 5*s.* to 10*s.* 10*d.* an hour. Trucking and palletisation of cargo by the North of Scotland Shipping Company at Leith has increased their dockers' hourly rate, through bonuses, by 3*s.* 6*d.* an hour.

Despite reports of this nature, port operations where work is almost 100% materials handling have lagged behind current industrial mechanisation. Only in the movement of bulk cargoes, modernised in post-war years, have new handling systems been satisfactorily applied. Change was relatively easy here for two reasons: bulk cargo carriage has grown with many new terminals being built from scratch, often away from established dock areas; and labour content is far smaller than in the movement of general cargo. Great savings in time and transport costs have resulted. Iron ore, grain, or coal can be shot into ships and sucked or grabbed out of them at the rate of 1000 to 2000 tons an hour. Britain's normal handling rate for *general cargo* (approximately 6–8 tons an hour per hatch) could be increased likewise with industrial trucks and other mechanical handling aids.

Shipowners should well remember Britain now owns only 18% of the world's tonnage, compared with 41% in 1939. Every ship now running must do more work. On average, ocean-going ships spend only 45% of their lives at sea: short-sea traders are sailing for under 40% of their time. Ships thus spend longer loading and discharging cargo than in carrying it.

Increased mechanisation for the loading and discharge of Swedish Lloyd ships, trading from the Tyne to Scandinavia, now allows one vessel to do the work of two. Palletisation and trucking has reduced the time for Swedish Lloyd vessels at Gothenburg from five days to one. Discharging and loading of Swedish ships in Britain has been reduced from one and a half days to five *hours*. These savings mean that a round trip (Gothenburg–Leith–Newcastle) takes a week, opposed to a fortnight as before. Quicker handling with modern materials handling equipment has permitted both the Swedish Lloyd and Bergen Lines to carry the same amount of cargo annually with one ship instead of two.

Mechanisation can reduce damage and cheapen handling costs for port authorities and stevedoring concerns. It will also attract more trade to ports through speedier and safer handling, and quicker turn-round. When one considers the resources marshalled by shipbuilders and marine engineers to reduce by the merest fraction the operating costs of a ship at sea, it is amazing how little concerted effort is put into reducing time in port.

The mechanisation of British ports is an issue which is being discussed by many parties with various points of view. Co-ordination of those views to help introduce increased mechanisation in Britain's ports is one of the nation's most urgent needs.

THE CROWN AND SCIENCE: ELIZABETH I TO ELIZABETH II

Prof. DOUGLAS McKIE, Ph.D., D.Sc., F.R.S.E.
Department of the History and Philosophy of Science, University College, London.

The connexion of the monarchy with science goes back to Elizabeth I, and was so intimate in the days of Charles II that it resulted in the foundation of the Royal Society. Ever since, close relations between Britain's monarchs and science have continued and are closer today perhaps than ever before.

Celebrations on a scale commensurate with the importance of the occasion and attended by representatives from all quarters of the world are about to be held in London to mark the tercentenary of the foundation of the Royal Society in that "wonderful pacifick year" of 1660 that saw "the happy Restoration" of King Charles II, now being particularly remembered as the founder of the Society. These celebrations cannot fail to recall, however, the close connexion of others of our monarchs with the science and the scientists of their times, a connexion that goes back even beyond Charles II to Elizabeth I. The great Tudor queen, last of her dynasty, numbered among her Court officials Dr William Gilbert of Colchester (1544–1603).

ELIZABETH I

Gilbert was the Queen's physician and he was also the first "natural philosopher", the first to put into practice the "new philosophy" or the new way of studying Nature by means of experiments. In this enterprise, it is often forgotten, he preceded Galileo. Before Gilbert's time, when any question arose on what we would now call a "scientific" problem, it was customary to refer for an answer to the ancient authorities and writers, especially to the works of Aristotle, and then it was usually necessary to debate according to the principles of an elaborate system of logic the meaning of what might be found there supposedly relevant to the problem that had arisen; it was all words and logic-chopping without experiment, and modern science began only when this way of going about things was rejected in favour of experiments.

Gilbert was mainly interested in magnetism and to a less extent in electricity. Having made a spherical loadstone or magnet, a kind of miniature Earth or *terrella* as he called it, he took a small *versorium* or pivoted compass-needle; by applying the *versorium* to the *terrella*, marking the direction in which the former pointed and then moving it forward in that direction and

FIG. 1. Dr William Gilbert showing his experiments on magnetism to Queen Elizabeth I and her court. A painting by A. Acland Hunt presented by the Institute of Electrical Engineers to the Corporation of Colchester in commemoration of the scientific achievements of Dr Gilbert on December 10, 1903, the 300th anniversary of his death. *(Reproduced by permission of Colchester Borough Council)*

again marking its direction in its new position, he showed that the *terrella* had two magnetic poles, diametrically opposite to one another, as well as the other known magnetic properties of the Earth, including the inclination or "dip" of the magnetic needle. The Earth thus appeared to be a great magnet; and the title of Gilbert's book, which was written in Latin and published in London in 1600, was "De magnete, magneticisque corporibus; et de magno magnete tellure; Physiologia nova", "On the magnet and on magnetic bodies, and on the great magnet Earth; a new Physiology". It was the first classic of modern, that is, experimental science.

According to tradition, Gilbert demonstrated his experiments before Queen Elizabeth, and this would seem very probable, since it is not easy to suppose that the Queen would not be anxious to know about the discoveries made by her physician, especially as they bore on the question of the navigation of her ships. The scene has been represented by the late Acland Hunt in a modern picture that now hangs in the Town Hall at Colchester.

This, however, was far from being the only connexion of Elizabeth with the science of her age. As many of her courtiers had done, including Lord Burghley and Sir Philip Sidney, she had visited and consulted John Dee (1527–1608), who is described as not only a mathematician but also an astrologer, although this was at a time when it was still the practice to seek advice from astrologers about propitious days and when their so-called "science" had not yet fallen into disrepute. Dee was to some serious extent given to necromancy and had made claims to have raised spirits by incantation, but, when in 1589 he had to return impoverished to England from his unfortunate journeys to the Continent in company with the alchemist Edward Kelly (1555–95), who was also forger and coiner, it was the Queen herself who helped him over his financial difficulties. Many years earlier at the outset of her reign he had been asked to advise about a propitious day for her coronation; she had often consulted him about her health and, at her command, he had gone abroad in 1578 to consult German physicians and astrologers for the same purpose; he had similarly in 1580 to prepare geographical descriptions for the Queen of new lands discovered by her subjects; and in 1583 he had written a treatise on the reform of the calendar. He had instructed and advised almost all the famous explorers and discoverers of Elizabeth's reign; and he long enjoyed the Queen's confidence and protection.

THE FOUNDING OF GRESHAM COLLEGE

But perhaps Elizabeth's most important influence in these matters resulted from the patronage and favour that she extended towards Sir Thomas Gresham (*c.* 1519–79), a wealthy City merchant, who acted very successfully as her financial agent and who was at one time her Ambassador in the Netherlands: he built the Royal Exchange and founded at Osterley the first paper-mill in England. The Queen had visited him both at his country house at Osterley and in London. In his will he left his house in Bishopsgate Street for a college, Gresham College, to be endowed and maintained by the revenues derived from the Royal Exchange. There were to be seven resident professors in the college, distinguished in their special subjects of divinity, law, physic, geometry, astronomy, rhetoric, and music. The college was instituted in 1596 and lectures, which were open

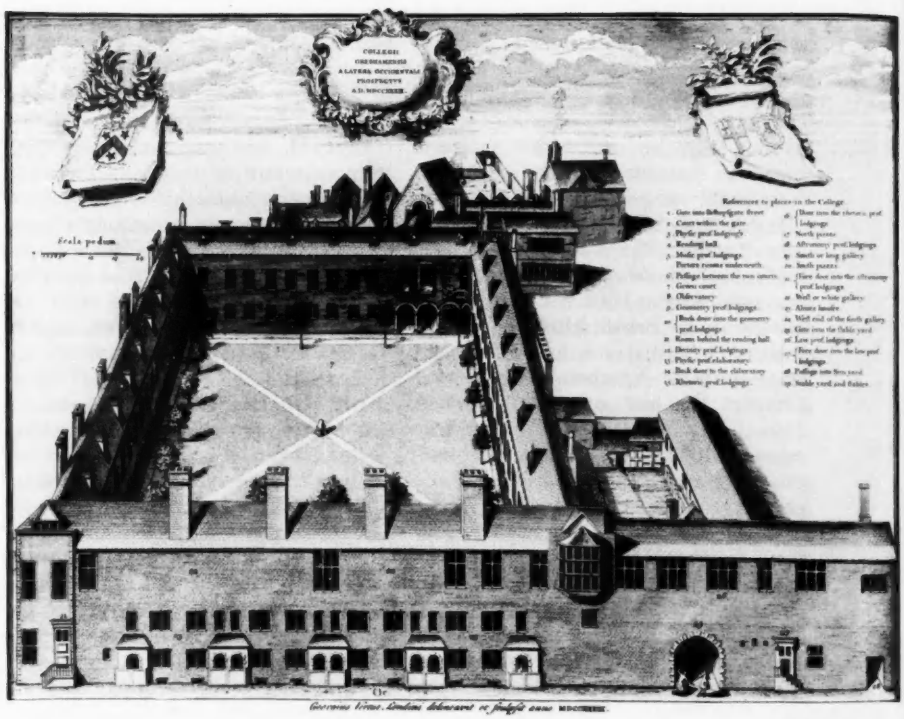


FIG. 2. Gresham College. An engraving from John Ward's "Lives of the Professors of Gresham College" (London, 1740). *(By courtesy of the Royal Society)*

to the public, began in 1598. The professorships of geometry and of astronomy in Gresham College date from 1596 and were the first professorships of science to be established in England, the Savilian chairs of geometry and of astronomy in Oxford not being instituted until 1619, almost a quarter of a century later.

Thus Elizabeth I was the first English sovereign to include among her subjects professors of science: Edward Brerewood (*c.* 1565–1613) of Brasenose College, Oxford, first Gresham professor of astronomy, and Henry Briggs (1561–1630) of St John's College, Cambridge, first Gresham professor of geometry. (Briggs afterwards became first Savilian professor of geometry in Oxford in 1619). While most of Brerewood's writings on mathematics were published posthumously and are of interest only to specialists, Briggs will always be widely remembered for his introduction of logarithms to the base 10, although he published other mathematical studies. Gresham College was afterwards the birthplace of the Royal Society, and the first influence towards its foundation may thus be traced back to Elizabethan times.

JAMES I AND CHARLES I

The times of James I and Charles I were not greatly favourable to the progress of science in England, although it was in Gresham College in 1645, or possibly sooner, in the reign of Charles I, that there began the first informal meetings that subsequently led to the foundation of the Royal Society by Charles II in 1660. Under James I the first London *Pharmacopoeia* (of the College of Physicians, as it then was) was published in 1618; the King's copy is now in the British Museum. A year earlier, in 1617, James had constituted the Society of Apothecaries by Royal Charter. He had supported William Harvey (1578–1657) for his appointment in 1609 as physician to St Bartholomew's Hospital. In 1616 Harvey gave his first course of lectures at the London College of Physicians and in these discourses he outlined his theory of the circulation of the blood. In 1618 he was appointed physician to the King.

He similarly served Charles I, whom he accompanied to Scotland; and he was with the King at Edgehill in 1642, the two princes (twelve and ten years old) being placed in his care during the battle. After the surrender of Oxford in 1646 and the end of the First Civil War, Harvey resigned all his appointments, gave up his practice, and went into retirement. During his attendance on the King in Oxford, he had been in danger of losing his appointment in St Bartholomew's Hospital, "because he hath withdrawn himself from his charge, and is retired to the party in arms against the Parliament".

Charles I had protected him and been his patron, placed the royal herds of deer at his disposal for his studies on generation, and taken keen interest in his experiments on the growth of the chick and in his demonstration of the movements of the living heart. During his absence on service with the King, Harvey's lodgings and furniture in Whitehall were searched; also, as he afterwards bitterly complained, his manuscripts and his anatomical preparations were seized, an irreparable loss. He was, of course, not likely to be popular with those in authority in London at that time because, apart from his having taken the opposite side, he had dedicated to Charles I his "De motu cordis et sanguinis", the classic in which in 1628 he described his discovery of the circulation of the blood.

ORIGINS OF THE ROYAL SOCIETY

In 1645, however, during the Civil War, a group of those interested in "the new philosophy" of studying Nature by means of experiments began to meet in London, first in the lodgings of Dr Jonathan Goddard in the City, and then near by at "The Mitre" in Wood Street, and shortly afterwards at "The Bull Head" in Cheapside, but during term-time in Gresham College in the lodgings of the professor of astronomy, Samuel Foster. After Foster's death in 1652 they met in the lodgings of his successor in Gresham College, Laurence Rooke, or in some convenient spot in the neighbourhood. When the First Civil War ended in the defeat of the Royalist forces, there followed a purge of their supporters from the colleges in Oxford and their replacement by nominees of the Parliament. Among members of the group

FIG. 3. A sketch of Charles II, used as frontispiece to the Royal Society's volume of facsimile signatures from the Charter Book. *(By courtesy of the Royal Society)*

meeting in or near Gresham College now "intruded" into appointments in Oxford were John Wilkins in 1648 as Warden of Wadham College, John Wallis in 1649 as Savilian professor of geometry, and Jonathan Goddard in 1651 as Warden of Merton College. As a result of these migrations, meetings for the study of "the new philosophy" now began in Oxford, especially under the influence of Wilkins, while at the same time the meetings in London continued. Those meeting in Oxford were joined by Petty, Boyle, and Willis, among others.

Then, with the Restoration in 1660, the numbers meeting in Gresham College were much increased "by the accession of divers Eminent and Noble Persons upon his Majesties Return". On November 28, 1660, those attending these assemblies in Gresham College formally constituted themselves into a society "according to the Manner in other Countryes, where there were voluntary associations of men into Academies for the advancement of various parts of learning, So they might doe something answerable here for the promoting of Experimentall Philo-

sophy". The company now consisted almost exclusively of Royalists, as might be expected, and they recruited others like-minded to join with them. The most active among them all was Sir Robert Moray, who had served in exile with Charles II, whom he kept informed of these proceedings in which the King was much interested. A week after the meeting of November 28, Moray brought word to the following meeting on December 5 that the King "had been acquainted with the designe of this meeting. And he did well approve of it, & would be ready to give an encouragement to it." Later, Charles discussed with Moray and with Evelyn the name of the Society; and, when he received a petition for a royal grant of incorporation from the society, he not only acceded to it, but also "hee was pleased to ofer of him selfe to bee enter'd one of the Society". The Charter of Incorporation passed the Great Seal on July 15, 1662, and thus the "Society for the Promotion of Physico-Mathematicall Experimentall Learning" became "The Royal Society of London" with the King as Founder and his brother James, Duke of York, a Fellow of the Society. In 1663, Charles presented to the Society the Mace that is still in use today.

A wrong emphasis has often been placed on Charles's laughing about the Fellows of the Royal Society for doing nothing but weighing of air, as if he regarded their work as trivial and amusing; he laughed also and on the same occasion at Petty's double-keeled ship. But Charles enjoyed such banter directed against those whom he liked, and his interest in the Society and its work is clear from many details recorded in his time. He talked with Evelyn about the work of the Fellows and their astronomical observations; on occasion he gave them various objects, such as, for instance, loadstones and Prince Rupert's Drops; and he often remembered them in another way by sending gifts of venison for their anniversary dinners on November 30.

"A PHILOSOPHICALL KING"—CHARLES II

Of Charles's wider interests in science there is more to be said; and Petty is reported as having rejoiced that England "now had a Philosophicall and Mathematico-Mechanicall King", while Boyle wrote from Kensington on December 12, without giving the year, that: "I was yesterday at *Whitehall*, and was informed, that his majesty is learning something of the mathematics, and that, as they say, of your brother, the bishop of *Salisbury* [Dr Seth Ward, Fellow of the Royal Society]. Whilst I was there, the king sent for Mr Mercator to come to him; but he being not found in the way, I could not learn of him, as I else might have done, what service was required of him; but was only confirmed, in the general, that his majesty's laudable curiosity now applies itself to mathematical enquiries; which *Plato*'s prognostic about philosophising monarchs will, I presume, make no unwelcome news to you. . . .".

Nicholas Kauffmann or Mercator (1620–87), F.R.S., mathematician and astronomer, spent some time in England and afterwards, when he had left for France, worked on the construction of the fountains at Versailles. Charles also spent much time in his chemical laboratory, which he had built in Whitehall. There he often watched the experiments of his chemist, Nicasius Lefebvre (*d.* 1669), whom he had brought from France in 1660 from the post of demonstrator of chemistry in the Jardin du Roi in Paris to be "Royal Professor of Chemistry to his Majesty of England". Lefebvre was the first professor of chemistry in England; he wrote an excellent treatise on chemistry, dealing both with its theory and its practice, the book appearing both in French and in English and being notable for its exactness and its practical detail. He was an Original Fellow of the Royal Society, to which he had been elected in 1661 before its incorporation by Royal Charter.

Charles II was much interested also in all that pertained to navigation. He founded the Observatory at Greenwich (later the Royal Observatory) in 1675 for the improvement of navigation and nautical astronomy so as to obtain more accurate data "for the use of his seamen". His first "Astronomical Observator", as the Astronomer Royal was then called, was John Flamsteed (1646–1720). Samuel Sorbière, historiographer to Louis XIV, when visiting England in 1663, observed the King's interest in chemistry and in navigation and in the Royal Society. In the English translation of his "Voyage" we read: "The King himself is not devoid of this Curiosity; nay, he has caused a Famous Chymist to be brought over from *Paris*, for whom he has Built a very Fine Elaboratory in St *James*'s *Park*: But his Majesty more particularly takes great Delight in finding out useful Experiments in Navigation, wherein he has immense Knowledge. He ordered my Lord *Bronker*, while I was at *London*, to try some sort of Timber, and what Form could swim best on the Water, or easiest sink; upon which Occasion I heard them discourse of a Ship with Two Keels, that carried Two Foremasts, and having Two Sails, drew more Wind, but less Water, and consequently must Sail faster than others. I do not know whether the Project took Effect; but this in general is very true, that the King's Curiosity, and that of the Nobility, has deeply engaged them in the Pursuit of Natural Philosophy: Since his Majesty has readily given Ear to the Proposals made to him for erecting an Academy, of which there never was the like in the World, if the Project comes to be entirely put in Execution."

In 1671 there had apparently been some discussion about whether air could be compressed by water, and the King had taken part, it seems, in the discussion, and had argued for the affirmative. The pressure of air was itself something of recent recognition and demonstration, particularly by Boyle in 1660. On January 12, 1671, according to Birch, one of the historians of the Royal Society: "Sir Robert Moray mentioned, that the King had laid a wager of fifty pounds to five for the compression of air by water; and that it was acknowledged, that his Majesty had won the wager. Sir Robert desired, that the experiment formerly made for evincing this fact might be made before the society, and afterwards before the King; which he said might be done by a cane [a glass tube] contrived after such a manner, that it should take in more and more water, according as it should be sunk deeper and deeper into it." Hooke was therefore instructed to prepare the apparatus. A fortnight later, on January 26, it was reported to the Society that "An experiment was made of compressing air by water, which was done in a large

tube of six feet long, filled with water, and by letting into it a syringe open at one end, in which the air was at the depth of two feet and a half compressed about one inch, and at the depth of five feet near two inches".

JAMES II

James II continued his brother's interest in all matters relating to navigation with which as Lord High Admiral he was closely concerned; and as a sea-going admiral he possessed a detailed professional knowledge of seamanship. However, the outstanding scientific event with which he was associated as King, and as Patron of the Royal Society, was the publication in 1687 of Newton's "Principia" under the imprimatur of the Society. Edmund Halley, who had seen the book through the press, presented a copy to the King with a letter summarising the contents of the book and giving a simplified explanation of the cause of the tides. The explanation is the one commonly given today; it is inexact, since it is expressed in terms of statics rather than dynamics; but it has proved useful both then and since. It was reprinted in the *Philosophical Transactions*, where it is disarmingly stated: "Now this Paper having been drawn up for the late King James's Use, (in whose Reign the Book was publish'd) and having given good Satisfaction to those that got Copies of it; it is hoped the Savants of the higher Form will indulge us this Liberty we take to gratifie their Inferiours in point of Science; and not be offended, that we here insist more largely upon Mr Newton's Theory of the Tides, which, how plain and easie soever we find, is very little understood by the common Reader." Halley's explanation of the tides, formulated for James II, is still offered today to the general reader and it is usually shown in diagrams in the opening pages of an ordinary atlas.

Before his accession, James, as Duke of York, had been a most efficient reformer in the administration and organisation of the Navy. He had bought from Kuffler two of the 'secrets' invented by Drebbel, namely, the bread-oven, which was thermostatically controlled by a simple device, and the distilling furnace, so that "ships will never lack fresh bread nor water, and men who go to the Indies having these two refreshments will never have scurvy". After his abdication, while on a visit to the Paris Observatory in 1690, James so impressed the French astronomers with his knowledge both of nautical astronomy and of its application to navigation that a detailed *procès-verbal* of the proceedings was drawn up and entered in the registers of the Académie Royale des Sciences.

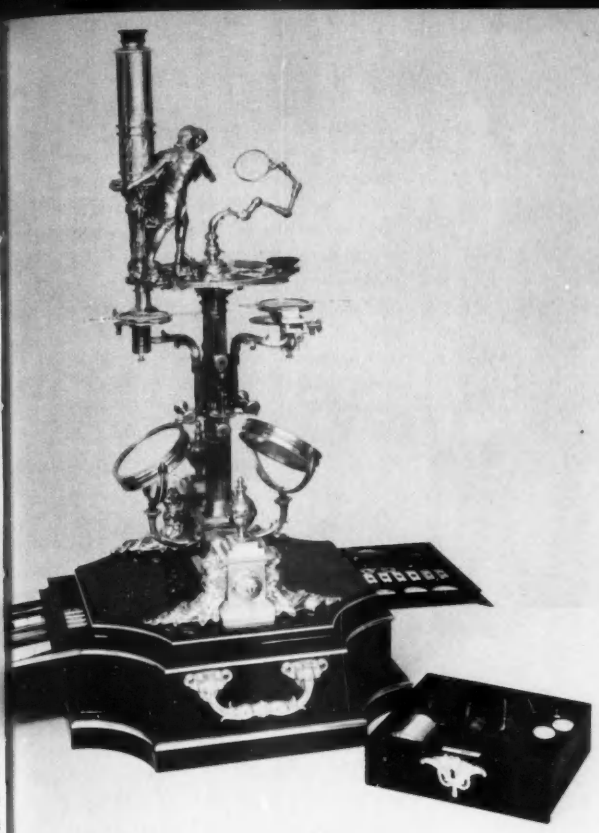
During the reign of William III and Mary (1688–94) and after Mary's death in 1694, when William reigned alone until 1702, there seems to have been little connexion between the throne and the scientific world except that Newton was appointed Warden of the Mint in 1696 and Master in 1699. From Queen Anne, in 1705, Newton received the honour of knighthood, being the first English scientist to be so distinguished for his scientific work. It was over a hundred years before this was repeated, when Davy was knighted in 1812. When she was about to send an ambassador to Moscow in 1713, the Queen directed that her ambassadors and governors sent abroad should correspond with the Royal Society, as occasion demanded, and that they should reply to the Society's inquiries: in 1710 she had appointed the President together with a number of Fellows to be Visitors to the Royal Observatory at Greenwich, an arrangement which, with modifications, has persisted since that time. The Queen's Consort, Prince George of Denmark, elected F.R.S. in 1704, generously undertook to pay for the printing of Flamsteed's star-atlas, the "Historia Coelestis Britannica", which was "designed for the benefit of navigation".

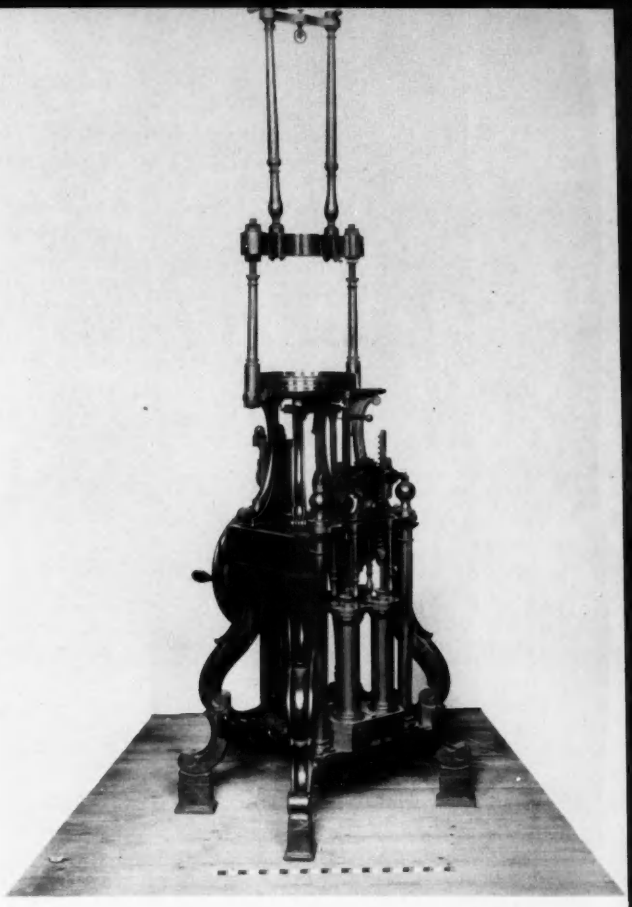
GEORGE III

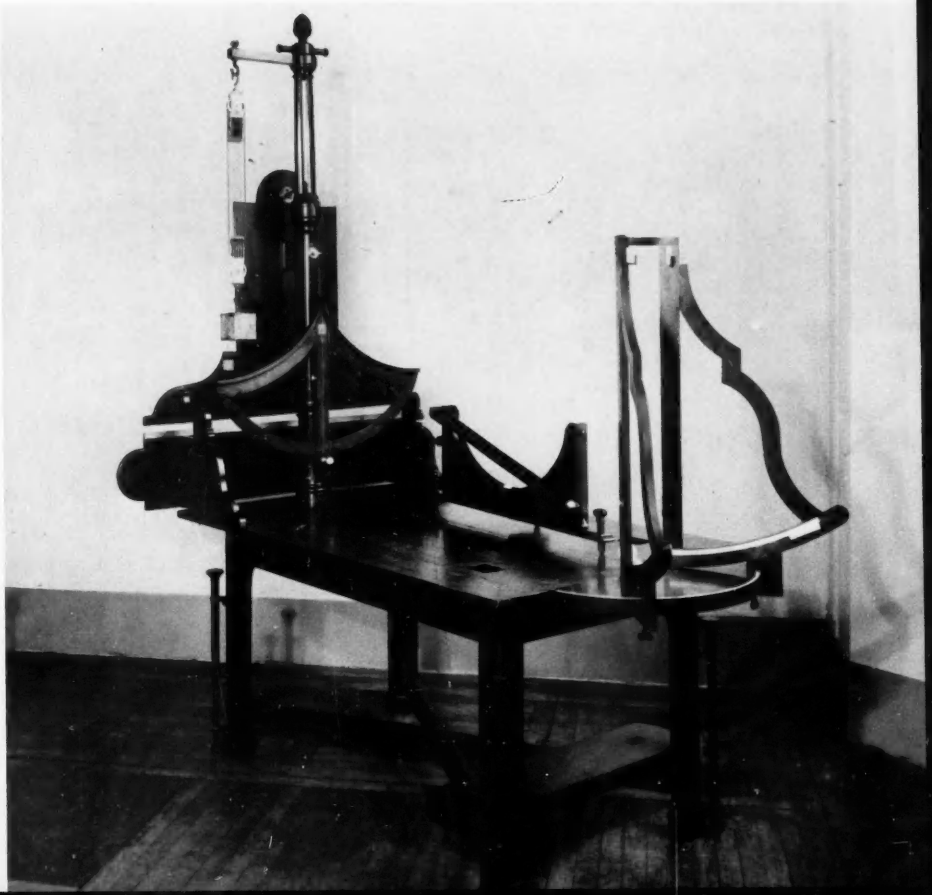
Among the Georges, so far as science was concerned, George III, "Farmer George", interested in agriculture and in all things mechanical and scientific, and beloved of his people, was outstanding. Soon after his accession in 1760 he ordered £1600 to be paid to the Royal Society for expeditions to observe the transit of Venus in 1761; and in 1768 he ordered a further payment of £4000 for observations of the later transit in 1769, again as the Society's "Memorial" states for "the improvement of Astronomy, on which navigation so much depends". He further directed that any surplus from this second grant should be placed to the credit of the Society. There was a surplus, a part of which the Society used for a marble bust of the King by Nollekens, which now stands in the entrance hall of the Society's rooms in Burlington House. In 1784, George again ordered a sum of money (£3000) to be paid to the Society for the geodetic triangulation from Greenwich to the coast of France, which was then being made expressly to determine the difference in longitude between the observatories of Greenwich and of Paris. A year later, in 1785, he gave £4000 for the construction of the great 44-ft. reflecting telescope designed by Sir William Herschel, erected at Slough and brought into use in August 1789. George III's close interest in scientific problems was remarkable, and so was his grasp of their significance and importance. Besides his munificence towards the researches and the scientific work already mentioned, there was also his support of "Longitude Harrison", the inventor of the marine chronometer, when the Board of Longitude favoured a method based on stellar rather than chronometric observations.

In 1772, on the death of his mother, Princess Augusta, the King, who had shared her interest in gardens and in the collection of plants, extended the botanic garden that the Princess had begun in 1760 at Kew. He called in as his adviser Sir Joseph Banks, who was afterwards President of the Royal Society for forty years; and through the King's active interest and under Banks's direction, Princess Augusta's garden, since known in its greatly enlarged state as the Royal Botanic Gardens, was carried forward a great way towards its present world-wide scientific importance as a Mecca of all botanists.

During George III's long reign, one very important Royal Charter was granted in 1800 to a scientific body, namely, the Royal Institution, founded in 1799 primarily to spread a knowledge of the applications of science, but soon, through the genius of Humphry Davy, to transcend its original aims and to become the first scientific research institution.







A KING'S SCIENTIFIC INSTRUMENTS

FIG. 4 (*above, left*). An ornate silver microscope made in 1761 for the Prince Regent by George Adams. The King's own microscope is in the Museum of the History of Science, Oxford.

FIG. 5 (*above, right*). Air pump with two barrels made in 1761 for demonstrating experiments with vacuum.

FIG. 6 (*right*). King George III's famous Philosophical Table, also made by George Adams, in 1762, used for demonstrating experiments in mechanics. As seen in the photograph, it is rigged to demonstrate the action of a compound tackle of pulleys, cycloidal pendula, and the line of motion down an inclined slope.

(Crown copyright. Reproduced by courtesy of the Science Museum, South Kensington where these superb instruments are on exhibit)

(By courtesy of the Royal Institution)

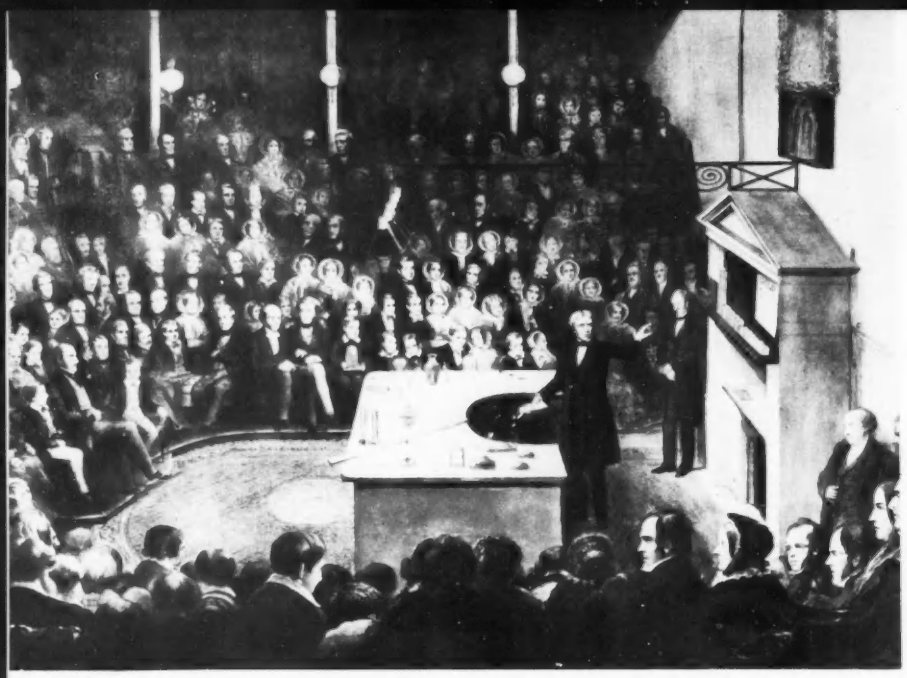


FIG. 7 (*above*). Michael Faraday lecturing on Metals at the Royal Institution on December 27, 1855, during one of the famous Christmas lectures. H.R.H. Prince Albert, accompanied by H.R.H. Albert Edward, Prince of Wales (*b.* 1841), and H.R.H. Alfred Ernest, Duke of Edinburgh (*b.* 1844).
(*By courtesy of the Royal Institution*)

FIG. 8 (*below*). T.R.H. the Prince of Wales and the Duke of York at the Roya Institution for a lecture by Prof. James Dewar on Liquid Air, on February 22, 1893. The President of the Royal Institution at the time was the 6th Duke of Northumberland. In the distinguished audience were Lord Rayleigh, Lord Helvis, Lord Playfair, and Prof. T. H. Huxley.
(*By courtesy of the* Illustrated London News)

Among George III's sons, his successor, George IV, is remembered as having instituted the Royal Medals of the Royal Society in 1825. His sixth son, the Duke of Sussex, was President of the Royal Society from 1830 to 1838.

A word must be said, although brief and inadequate, about the great collection of scientific instruments formed by George III. Formerly housed in Kew Observatory, the collection was intended mainly for the instruction of the Royal children. The scientific apparatus and instruments thus brought together ranged over the fields of astronomy, electricity and magnetism, mechanics, optics, chemistry, pneumatics, acoustics, and surveying. Terrestrial and celestial globes, telescopes (reflectors and refractors), ring-dials, heliostats, heliometers and micrometers, electrical machines, Leyden jars, electroscopes, thermometers, microscopes, and many other instruments are all well represented in the collection, much of which is now in the Science Museum, London.

QUEEN VICTORIA AND PRINCE ALBERT

During the course of Queen Victoria's long reign from 1837 to 1901, science in its application to industry began to assume its now familiar role in our modern world. In this development the Queen's Consort, Prince Albert, wielded great influence; and his active interest in science and technology was an important factor in what is often referred to as the 19th-century scientific revolution, that is, the rise of modern applied science and technology. Through the work of Liebig, the Prince had early become aware of the importance of chemistry in industry and manufactures; and in 1845, as first President of the newly instituted Royal College of Chemistry in London, he had been influential in bringing to England as the Royal College's first Professor of Chemistry August Wilhelm van Hofmann (1818–92), then a *privat-dozent* in the University of Bonn. Hofmann returned to Germany in 1863, but he had left his mark on the development of chemistry in England, especially by ensuring that it was not merely the teaching of chemistry that he was concerned with, but also the training of his students in research.

At the Royal College he was succeeded by Edward Frankland; his most famous student was William Henry Perkin, the discoverer of the first aniline dye. In 1872 the College moved to South Kensington to be merged into the Royal College of Science.

It is not too much to say that it was the Prince's enthusiasm and his backing that led to the success of the Great Exhibition of 1851. His memorable Presidential Address to the British Association in 1859 at Aberdeen emphasised the interdependence of all branches of science and the necessity of their integration; and, as Chancellor of the University of Cambridge, he led the movement for increased teaching of science in the universities. He supported the application of science to our oldest industry, agriculture, as well as to the latest industrial developments of the mid-Victorian age. His early death in 1861 removed a great patron of science and the arts.

QUEEN ELIZABETH II AND PRINCE PHILIP

In our own time, in this 20th century, the most significant association of the Crown with science in its practical applications was the opening by Her Majesty the Queen of the Calder Hall Nuclear Power Station on October 17, 1956. For the first time, electricity from the new source of power, the "atomic energy" released by the fission of uranium, flowed into the national "grid"; and Queen Elizabeth II on this occasion might well recall the tradition that her great predecessor, Queen Elizabeth I, three and a half centuries ago witnessed William Gilbert's experiments on magnetism. We may close this brief survey by reference to the remarkable Presidential Address of Her Majesty's Consort, Prince Philip, to the British Association at Edinburgh in 1951, in which, after a survey of science and its applications in Britain during the previous hundred years, he urged that science should be used for the benefit of mankind, reminding his audience that "The instrument of scientific knowledge in our hands is growing more powerful every day; indeed it has reached a point when we can either set the world free from drudgery, fear, hunger, and pestilence or obliterate life itself".

On July 18, at the opening ceremony of the tercentenary celebrations of the Royal Society of London, the presence of Queen Elizabeth II accompanied by Prince Philip fittingly commemorates the long association of the British Throne with British Science.

FIGS. 9 and 10. Queen Elizabeth II and Prince Philip have shown a constant interest in science and have on numerous occasions visited scientific establishments and Britain's industrial achievements. H.M. the Queen is shown (*above*), in June 1958, inspecting the Rothes Pit mine, near Kirkcaldy, Fifeshire, on her first descent of a coal-mine. (*Right*) Prince Philip is shown in November 1958, when he paid an informal visit to Wye College, near Ashford, Kent.

THE ROYAL SOCIETY TODAY

Dr D. C. MARTIN, C.B.E.
Assistant Secretary, The Royal Society

"NULLIUS IN VERBA"

Those who form the present Fellowship of the Royal Society are heirs to a great tradition. H. A. L. Fisher, the historian, wrote of the period of the Society's foundation in these words "The seventeenth century, which opens with the glowing dreams of Francis Bacon, closes with Isaac Newton's precise demonstration that the whole universe is one vast mechanism. Between these two names lies a long and splendid chapter of English scientific work, beginning with Harvey's discovery of the circulation of the blood in 1624 (reached only because he tested all his theories by experiment) carried on by Robert Boyle's epoch-making work in chemical science, illustrated by the foundation of the Royal Society and giving England a place in the intellectual life of Europe, which the insular reputation of a Shakespeare or a Milton could not have secured."

King Charles II, the Society's founder, in granting his Charter of Incorporation stated ". . . we look with favour upon all forms of learning but with particular grace we encourage philosophical studies, especially those which by actual experiments attempt either to shape out a new philosophy or to perfect the old", and he referred to the Fellows "whose studies are to be applied to further promoting by the authority of experiments the sciences of natural things and of useful arts to the glory of God, the creator, and the advantage of the human race".

Over the past centuries the Society has sought to carry out this chartered duty and the following quotation from an address to the Fellows by Sir Humphry Davy in 1820, when he became President, describes the spirit which animates the Fellowship today as accurately as it did 140 years ago: "Gentlemen . . . I trust that in all our researches we shall be guided by that spirit of philosophy, awakened by our great masters Bacon and Newton; that sober and cautious method of inductive reasoning which is the germ of truth and permanency in all the sciences. I trust that those amongst us who are so fortunate as to kindle the light of new discoveries will use them not for the purpose of dazzling the organs of our intellectual vision but rather to enlighten us, by showing objects in their true form and colours, that our philosophers will attach no importance to hypotheses except as leading to the research after facts so as to be able to discard or adopt them at pleasure, treating them rather as parts of the scaffolding of the building of science than as belonging either to its foundations, materials or ornaments; that they will look, where it be possible, to practical applications in science, not however, forgetting the dignity of their pursuit, the noblest end of which is, to exalt the power of the human mind, and to increase the sphere of intellectual enjoyment, by enlarging our views of nature and of the power, wisdom and goodness of the Author of Nature."

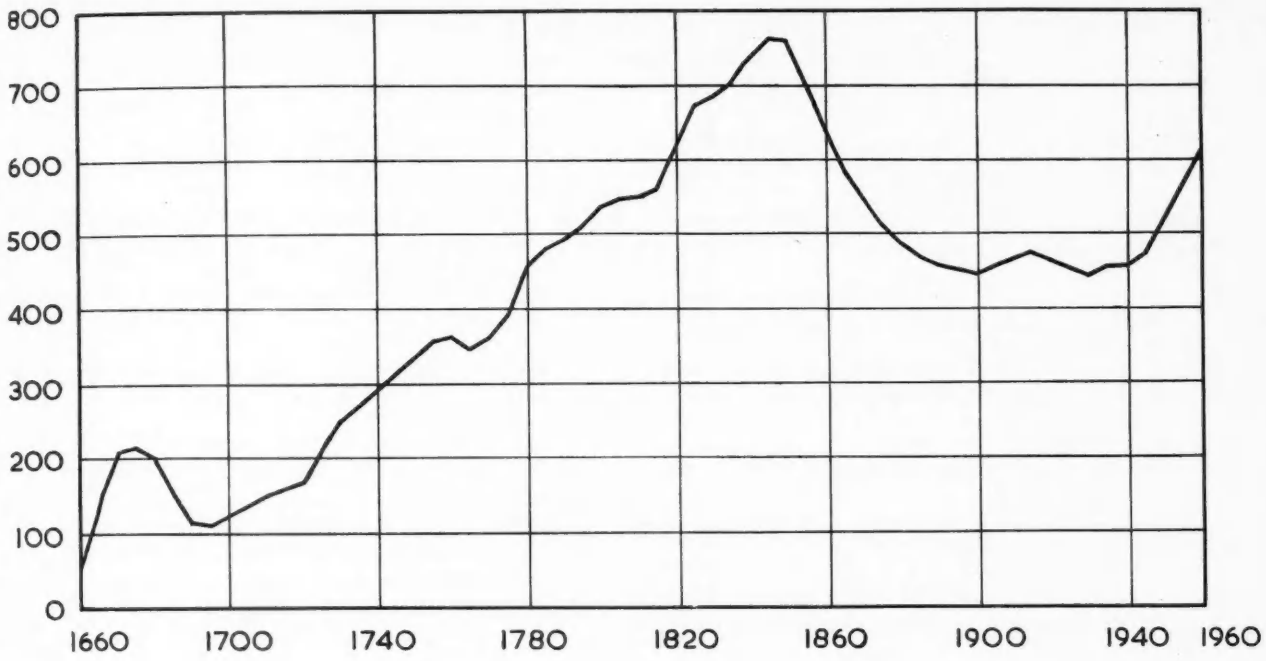
The tradition of devotion to knowledge for its own sake and the employment of this knowledge to the common good is maintained today by the Fellowship which constitutes this private and entirely independent body which is the Royal Society of London for the Improvement of Natural Knowledge. Its motto "Nullius in Verba" disclaiming the authority of any man and accepting the authority of experimental fact expresses a real state of affairs.

The Society is its Fellows and its Fellows are the Society. The independent researches of the astronomers, mathematicians, physicists, chemists, engineers, physiologists, botanists, zoologists, geologists, and others who have made reputations for themselves for their scientific work at the same time have enhanced that of the Society. The succession of names, such as Boyle, Wren, Hooke, Newton, Halley, Sloane, Cook, Banks, Davy, Faraday, Huxley, Darwin, Hooker, Kelvin, Lister, J. J. Thomson, Sherrington, Hopkins, and Rutherford gives sufficient point to this contention. Such men devoting themselves to research as their own genius prompted them also gave their time to the service of the Society in the conduct of its affairs. Because of widening responsibilities and increasing demands the time given by Fellows in support of the Society is greater today than ever in the past and the voluntary service of Fellows to the Society in advancing science is its chief source of strength, the importance of which cannot be overestimated. As Fellows are elected only after the most searching assessment, the fund of expert scientific advice on call to the Society is unequalled in any other national corporation.

THE FELLOWSHIP

At its Royal foundation the reigning monarch in Great Britain was the Patron of the Society and Her Majesty The Queen is the thirteenth monarch to continue this tradition. The number of Fellows and Foreign Members on April 1, 1960 is as follows: Patron and Royal Fellows (6); Fellows (616); Foreign Members (63). Among Royal Fellows are Her Majesty, Queen Elizabeth The Queen Mother, His Majesty King Gustav VI of Sweden, and His Royal Highness The Prince Philip, Duke of Edinburgh.

The way in which the growth of the Fellowship has varied in the past three hundred years is shown in Fig. 1. The number grew until it reached 764 in 1847. Previously from 25 to 30 and sometimes 40 to 50 candidates had been elected annually as permitted by the Charter, which conveyed the right to the Fellows as a body to elect as many as, and whomsoever, they pleased. In 1847 it was resolved to limit the number for election each year to 15 and to circulate to all Fellows the names of all the candidates. The selection of names for election was carefully done by the Council and was done in such a way as to choose only those whose qualifications were needed to raise the scientific reputation of the Society. This important reform set the pattern for elections which is still observed. By 1860 the number of Fellows



The growth of the Fellowship of the Royal Society over the last three hundred years.

had fallen to 630, of whom 330 were men with high scientific qualifications and for the first time these formed the majority of Fellows and soon thereafter the Society was almost wholly composed of men entirely devoted to the improvement of natural science. The number to be elected annually remained at 15 until 1930, the Fellowship then being 350. It was raised to 17 in 1931, to 20 in 1938, and in 1946 it was raised to 25 each year, the present figure. It was only in 1945 that women were first admitted as Fellows and on April 1, 1960 there were 15 women Fellows in the Society.

Foreign members are now elected at the rate of four each year and the roll includes most of the outstanding men of science of the world in the past three hundred years. In addition a statute of the Society permits the election of not more than one person annually who may be chosen in recognition of conspicuous service to the cause of science or because his election would be of "signal benefit to the Society". This statutory right is exercised rarely but under it Sir Winston Churchill is a Fellow of the Royal Society. Others are Lord Attlee and Lord Bridges, Viscount Bruce of Melbourne and the Marquess of Salisbury.

The regeneration of the Fellowship is quite the most important annual activity of the Fellows and the greatest care and attention is devoted to it. With a growth rate of 25 Fellows each year about half the Fellowship changes every 12 years. Every candidate, who must be a British subject or citizen of Eire, is proposed by at least 6 Fellows, of whom 3 must have personal knowledge of the candidate. Council is responsible for the assessment of claims and from 1916 Council has been assisted in this by the 8 Sectional Committees of the Society for the various scientific subjects. The candidates, which this year numbered over 300 for the 25 places, are classified and allocated to the committees for a first assessment and elaborate arrangements are also made for the consideration of candidates whose work lies in borderline subjects. The Council on receipt of the recommendations then has several further meetings before recommendations in favour of those considered the best from the whole list are made to the Fellowship which finally elects the new Fellows.

The present geographical distribution of Fellows and Foreign Members according to residence is shown in the accompanying maps.

Fellows in Government departments in the United Kingdom number 45 and those with industrial organisations number 35.

A recent examination of the ages of Fellows at election reveals that 372 of the total were elected before reaching the age of 50 years, all but 43 of these being between the ages of 35 and 49 years. The median age of election is different in the various subjects, as shown for a recent period (1954–9) in the following table.

Subject	*Median Age of Election*
Mathematics	41½
Physics	44
Chemistry	46
Engineering	52
Geology	49
Botany	48
Zoology	47½
Physiology	49

Comparison with an earlier period (1939–53) shows a slight but significant reduction in the age of election of Fellows.

THE OFFICERS AND COUNCIL

As prescribed in its Charters now nearly 300 years old the Society's business is conducted by the Council of the Society of which five of its members are Officers, namely the President, the Treasurer, the Physical Secretary (for the physical sciences), the Biological Secretary (for the biological sciences), and the Foreign Secretary (for international relations). The offices of President, Treasurer, and the first two Secretaries were named in the Charters and the post of Foreign Secretary was created, within the existing powers granted by the Charter, in 1823. At the same time the post formerly known as Clerk was renamed Assistant Secretary who, subject to such Standing Orders as shall be made, in the words of the Statutes "shall be charged with (1) the general administrative business of the Society, (2) the control of the offices and library and of all persons therein employed and the arrangement of the office work, (3) the conduct of the general correspondence."

Viscount Brouncker, the first President, held office for 15 years, Isaac Newton for 24 years, Hans Sloane for 14 years and Joseph Banks for 42 years. All others have served for shorter periods and starting with Sir Joseph Hooker in 1873 the period has, with very few exceptions since, been 5 years. The presidency now alternates between physical and biological scientists or, as it is customary within the Society to call them, scientists from the A side (for example, mathematics, physics, chemistry, engineering sciences) or the B side (geology, botany, zoology, physiology and other medical sciences). Thus the present President, Sir Cyril Hinshelwood, a physical chemist, succeeded Lord Adrian, a physiologist, and we may expect that the next President will be from the B side.

Regard is had to the desirability of a balance of scientific interests in selecting the body of Officers. Thus in the present group the President is a chemist, the Treasurer (Sir William Penney) is a nuclear physicist, the Physical Secretary (Sir William Hodge) is a mathematician, the Biological Secretary (Sir Lindor Brown) is a physiologist and the Foreign Secretary (Dr H. G. Thornton) is a microbiologist. The maximum terms of office for future Officers are Treasurer, 10 years, the Secretaries, 8 years, the Foreign Secretary, 5 years, subject always to the annual election by Fellows which takes place on St Andrew's Day (November 30).

The original Charter ordained that the size of the Council should be 21 Fellows and that 10 should change each year. This is, of course, done and 5 of the incoming persons must not have served on Council before. This 300-year-old arrangement has worked well and there has been no desire to seek another charter to alter it. The sectional committees for the various scientific subjects make suggestions to the Council which nominates its successors for election by the Fellowship. In this way each Council is representative of the whole range of scientific interests of the Fellows and is probably the most representative body of science in the country. It makes the Society's awards of medals, the senior of which is the Copley Medal founded in 1731, and is responsible for all appointments other than elections by the Fellows themselves. It meets formally eleven times a year and as a Committee of Council on several other occasions. Its members are nominated to sit on other of the Society's committees so that Council can be fully informed when reaching decisions on reports from such committees. Service on Council demands time and effort from Fellows; that it is given willingly and enthusiastically is characteristic of the attitude of Fellows to the well-being of the Society.

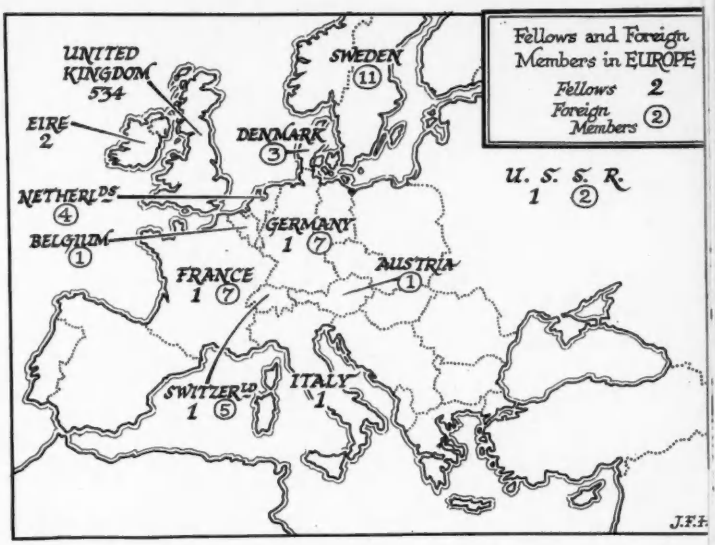
COMMITTEES OF THE SOCIETY—THEIR FUNCTIONS AND WORK

In addition to the sectional committees, one-third of the membership of which changes each year to ensure adequate representation of all aspects of each subject over a period of years, the Council is assisted by many other committees specifically appointed for particular tasks. In all there are 62 committees or boards assisted by 42 standing sub-committees and in addition there are 11 joint committees with other bodies which report to Council. The Society's committees can be regarded as being in four main categories: (*a*) those concerned with the domestic affairs or special projects of the Society itself; (*b*) joint committees; (*c*) those concerned with international relations; and (*d*) those concerned with the administration of Parliamentary Grants-in-Aid.

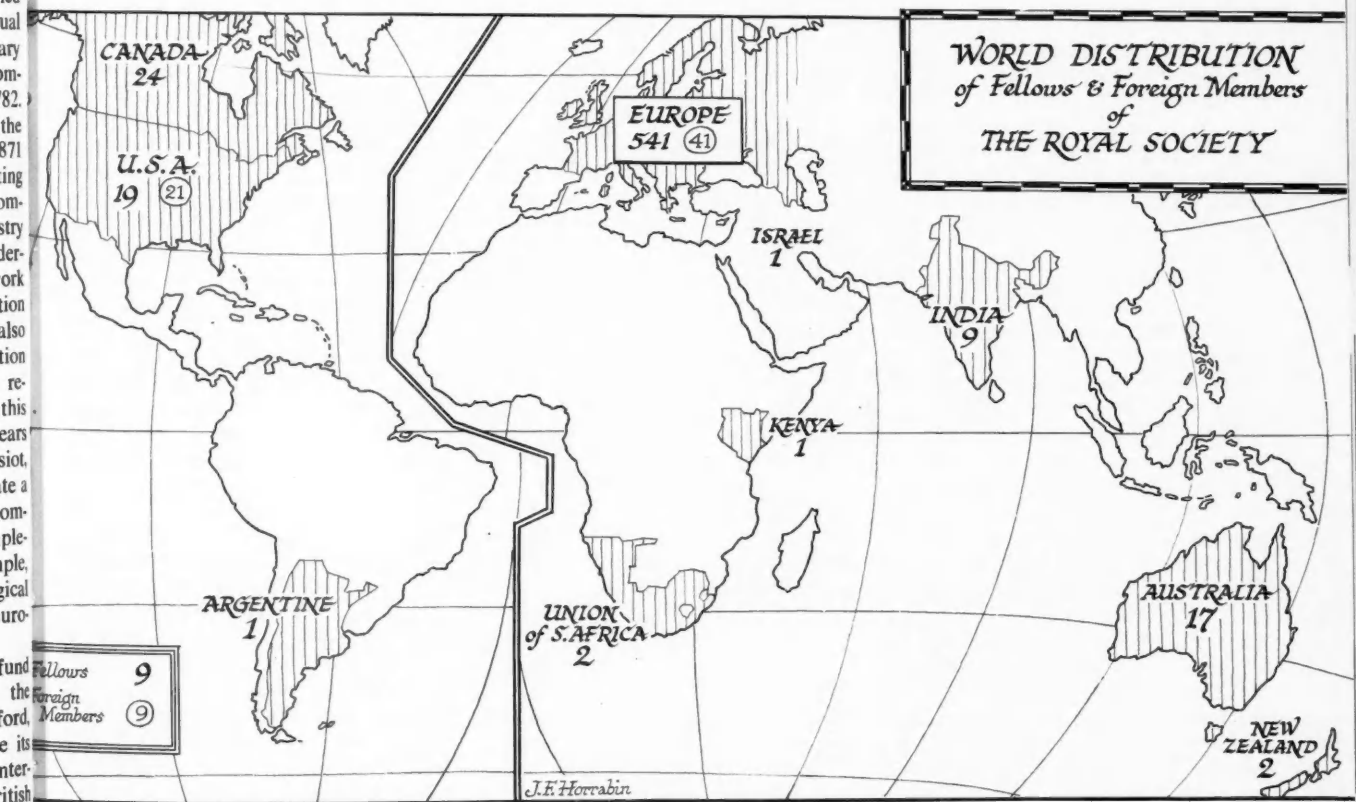
DOMESTIC AFFAIRS

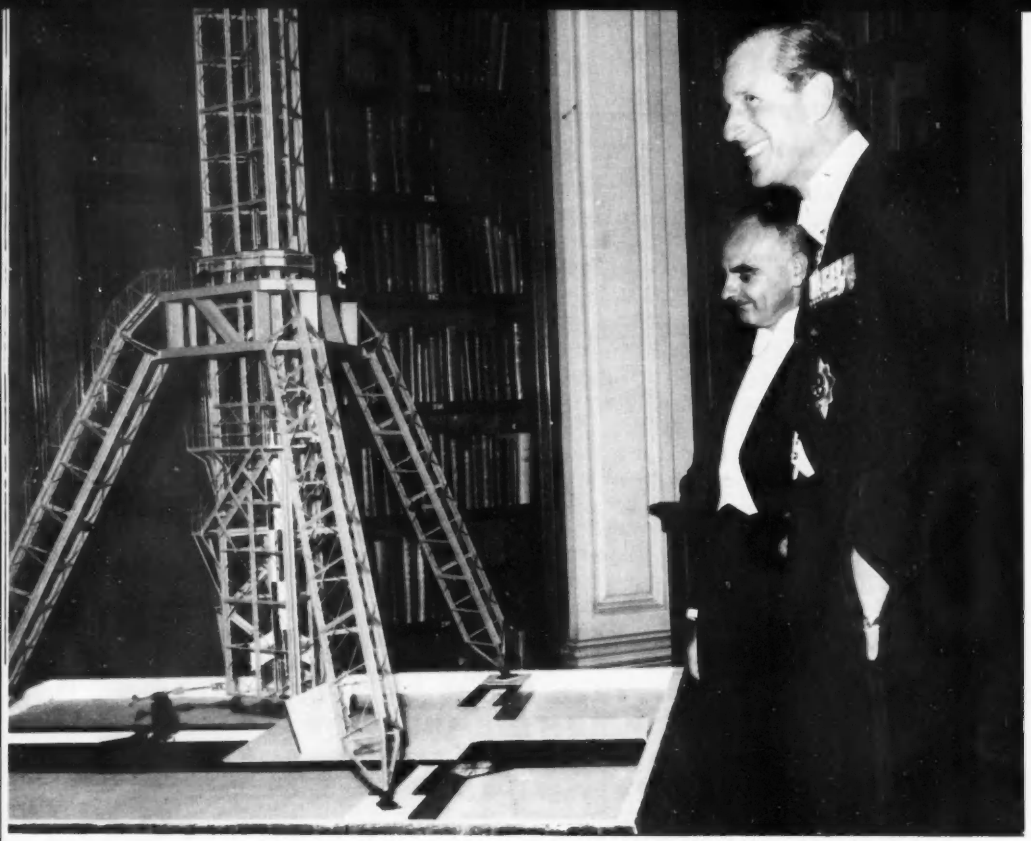
In general, membership of this group of committees is limited to Fellows. The sectional committees, in addition to the annual selection of candidates, are concerned with the acceptance of papers for publication by the Society and with other matters referred to them by the Council. Another group is concerned with the Society's finances, its annual conversaziones and the anniversary dinner, and includes the Library Committee created as long ago as 1782. Another long-standing committee is the Gassiot Committee founded in 1871 and which advises on matters relating to research in meteorology. This committee with the aid of an Air Ministry grant has for some years been undertaking a valuable programme of work at university centres on the radiation balance of the atmosphere. It has also pioneered Britain's rocket exploration of the upper atmosphere and was responsible for the first conference on this subject held in Oxford several years ago. It is named after J. P. Gassiot, F.R.S., who provided money to create a trust fund. A number of other committees likewise advise on the implementation of trust funds, for example, the Browne fund for marine biological research, and the Head fund for neurophysiology.

In 1950–1 the Society raised a fund by subscription to commemorate the services to science of Lord Rutherford, O.M., F.R.S., and decided to devote its annual income to encouraging the interchange of scientists within the British



DISTRIBUTION OF FELLOWS AND FOREIGN MEMBERS OF THE ROYAL SOCIETY IN BRITAIN, EUROPE, AND THE WORLD





Prince Philip and Prof. H. S. W. Massey, F.R.S. (now Sir Harrie), in front of a model of the launcher for the *Skylark* rocket at the IGY Conversazione held at Burlington House on June 28, 1957.

Commonwealth. Rutherford was born in New Zealand, did work in Canada, for which he received a Nobel Prize, and worked in England both at Manchester and the Cavendish Laboratory in Cambridge. The fund provides for a Rutherford Memorial lecturer to visit a country of the Commonwealth other than the United Kingdom and for the appointment of Rutherford Memorial Scholars who must carry out research work in a part of the Commonwealth other than that in which they first graduated.

Other committees, for example the Medical Sciences Research Committee and the Physical Sciences Committee, advise on research appointments made possible by generous benefactions received by the Society. In addition to the Foulerton Professor of the Royal Society (Prof. A. L. Hodgkin, F.R.S.), the Society maintains some 30 research fellows and scholars over a wide range of subjects. The recent magnificent gift of £200,000 from the Isaac Wolfson Foundation is a splendid addition to the Society's resources for the direct promotion of research. The names of these benefactors are commemorated by the funds which bear their name, for example, in addition to those mentioned, John Murray, A. R. Forsyth, John Jaffé, F. S. Locke, H. G. J. Moseley, Sir William Mackinnon, Rudolf Messel, Ludwig Mond, Sir Alexander Pedler, Albert Reckitt, E. W. Smithson, H. C. Sorby, J. H. Stothert, John Tyndall, H. B. Gordon Warren, Alfred Yarrow. These donors and others have enabled the Society to make appointments, always with great care and the best advice, of men and women of promise who later achieved distinction, many of them becoming Fellows of the Society. The appointments are so made as to attract the best applicants and the Society by being highly selective in making its awards can make the best use of the resources entrusted to it to encourage research in this manner.

As an example of a recently appointed committee for a project taken up by the Society mention might be made of the South Pacific Expedition Committee, under the chairmanship of Prof. C. F. A. Pantin, F.R.S., to study the south temperate zone. The Committee advised Council on the recent expedition to southern Chile led by Dr Martin Holdgate and in which participated three New Zealand and one Chilean scientist for the purpose of making a pilot floral and faunal survey of this little-explored area of the Southern Hemisphere. This highly successful expedition has promoted a great deal of interest which was manifest by the attendance of biologists from many nations including Australia, New Zealand, South Africa, Canada, Ceylon, Chile, the U.S.A., Norway, Sweden, Germany, and Finland at a Royal Society discussion meeting last December. The South Pacific Expedition Committee intends to continue its activities and looks forward to further co-operation from other countries especially those in the Southern Hemisphere.

The Scientific Information Committee with Sir Lindor Brown as its chairman was appointed in 1959 to keep under review developments in scientific information services. This revived in a formal way the Society's participation in a field in which it has a long and distinguished record.

JOINT COMMITTEES

Some of the joint committees are also concerned with making research appointments, for example, with a City company in appointing the Armourers and Brasiers' Company Research Fellow in Metallurgy. The Paul Instrument Fund Committee (jointly with the scientific societies) administers funds for the development of novel scientific instruments for physical research and the Commonwealth Bursaries Committee (jointly with the Nuffield Foundation) administers funds provided jointly by the Governments of the member countries of the Commonwealth and the Nuffield Foundation for the purpose of providing facilities for increasing the efficiency of scientists of proven ability by enabling them to pursue research or learn techniques where either or both the physical and personal environment overseas in a Commonwealth country is peculiarly favourable. Started in 1953 this scheme has given opportunities to many Commonwealth scientists, and generous as have been the contributions from all concerned the Committee could usefully apply to this service sums several times greater than it has at its disposal at present, about £10,000 per annum. It is a particularly valuable and rewarding co-operative Commonwealth scientific activity.

Jointly with the Science Masters' Association the Society in 1957 appointed a committee to assist school science teachers who wish to pursue research. The Committee in no sense proposes research problems. The proposals come from the teachers themselves. The Committee then invites a Fellow of the Society or some other senior scientist to become associated with the project and on the recommendation of this adviser the Committee is prepared to make grants for equipment. An excellent start has been made and fifty-seven active research projects are in progress. The interest and willingness of Fellows to act as advisers is one of the more stimulating aspects of this new venture.

Another joint committee of a completely different kind is the Defence Services Research Facilities Committee with representatives from the Admiralty, the War Office, the Air Ministry and the Ministry of Aviation, and through this committee scientists have obtained facilities for working in submarines and aircraft which might otherwise not have been possible.

INTERNATIONAL RELATIONS

In the field of international relations the Society acts for the United Kingdom as the adhering body to the International Council of Scientific Unions (ICSU) and its scientific members, namely, the international scientific unions for astronomy, biochemistry, biological sciences, chemistry, crystallography, geodesy and geophysics, geography, mathematics, physics, the physiological sciences, scientific radio, and theoretical and applied mechanics. Last year the Society proposed the formation of an International Union for Geology. To co-operate with all these international unions the Council is advised by a series of British National Committees, each representative of the national interest. Thus in the British National Committee for Chemistry the *ex officio* members are the appropriate Officers of the Royal Society, the Government Chemist, the Director of the National Chemical Laboratory, together with British chemists who hold senior offices in the International Union of Pure and Applied Chemistry. Also on the National Committee are representatives of the Chemical Society, the Society of Chemical Industry, the Royal Institute of Chemistry, the Society for Analytical Chemistry, the Biochemical Society, the Faraday Society, the Institution of Chemical Engineers, and nine other national bodies concerned with several aspects of applied chemistry. These national committees prepare an agreed viewpoint on matters concerning the international development of their subject, recommend to the Society's Council the appointment of delegates to Union meetings and from time to time initiate arrangements for meetings of the Unions and associated congresses when these take place in Great Britain. Two such meetings are to take place in this country this year: the International Union of Crystallography is holding a General Assembly and a congress in Cambridge in August and the General Assembly of the International Union of Scientific Radio meets in London in September. In both instances the appropriate National Committee recommended the issue of the invitation to other countries and the creation of an organising committee.

Another very important international activity is that sponsored by the International Council for Scientific Unions through its Special Committees, of which the first and best known has been that for the International Geophysical Year. These Special Committees seek to obtain an agreed plan for a programme of scientific investigation in which national efforts are co-ordinated through the Special Committee and its Officers. The success of the IGY provided an example which is being followed and Special Committees have been set up for Space Research, Oceanic Research, and Antarctic Research. The Royal Society has a special responsibility in representing the British contribution and National Committees exist for this purpose not only for the IGY but also for the other three Special Committees of ICSU. For the IGY Britain's considerable contribution from universities and Government departments was formulated into a programme by the Society and it is difficult to see how any better arrangement could have been made in this country. As part of this contribution the Society organised its IGY Antarctic Expedition and from 1956 to 1960 scientists at Royal Society Base, Halley Bay, carried out a programme of geophysical observation with first-rate results.

In space science the Society is likewise extremely well placed to co-ordinate British research work being carried out not only in universities but also in Government research establishments. With the work on rocket exploration already begun under the Gassiot Committee before the IGY and an artificial earth satellite sub-committee already in being before *Sputnik I* was launched on October 4, 1957, the Society has continued ever since to give leadership in Britain's space research programme. Within the limitations of finance available to it this programme has already been most creditable and won favourable commendation internationally, although Britain has not yet its own satellite launching vehicle. The Society has provided a forum for scientific discussions, promoted a programme at universities and has the strong and willing support of those in interested Government research establishments as well as

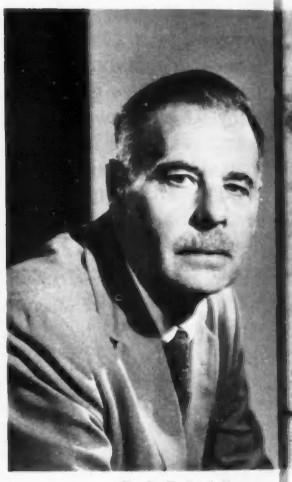
THE COUNCIL OF TH YA

Sir Cyril Hinshelwood, O.M., P.R.S.
Chemist

Sir William Penney
Treasurer and Vice-President
Physicist

Sir Lindor Brown
Secretary and Vice-President
Physiologist

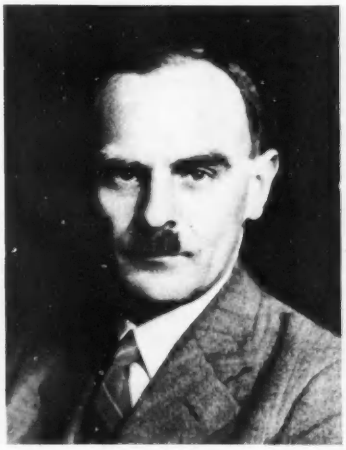
Prof. J. F. Baker
Engineer



Dr J. C. Burkill
Mathematician

Dame Kathleen Lonsdale
Crystallographer

Prof. R. A. Lyttleton
Astronomer



Sir Harrie Massey
Physicist

Prof. R. A. Morton
Biochemist

Acknowledgments

Sir Cyril Hinshelwood, Prof. Smith, Prof. Baker, Prof. Hawkes, Prof. Hodgkin, Dame Kathleen Lonsdale, Prof. Lyttleton, Sir Harrie Massey, Prof. Morton and Sir Alfred Pugsley by Walter Stoneman.

Sir Lindor Brown, Sir William Hodge, Dr Thornton, Sir Patrick Linstead and Dr Burkill by Walter Bird.

Prof. Harris, Prof. Pumphrey and Dr Thompson by Associated Press.

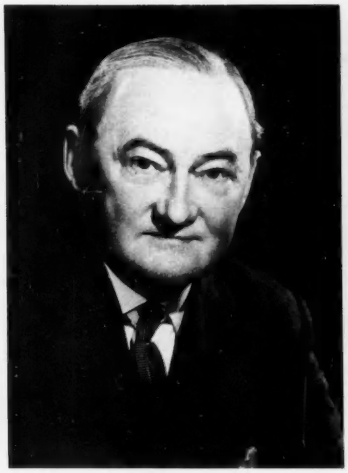
Sir William Penney by Shelburne Studios.

Prof. Catcheside by his son.

ROYAL SOCIETY 1960

Sir William Hodge
Secretary and Vice-President
Mathematician

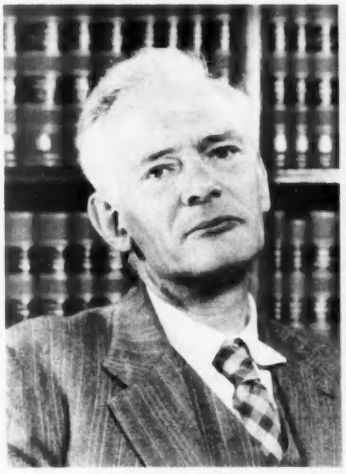
Dr H. G. Thornton
Foreign Secretary and Vice-President
Microbiologist



Sir Patrick Linstead
Vice-President
Chemist

Prof. W. Smith
Vice-President
Bacteriologist

Prof. D. G. Catcheside
Microbiologist



Prof. T. M. Harris
Botanist

Prof. L. Hawkes
Geologist

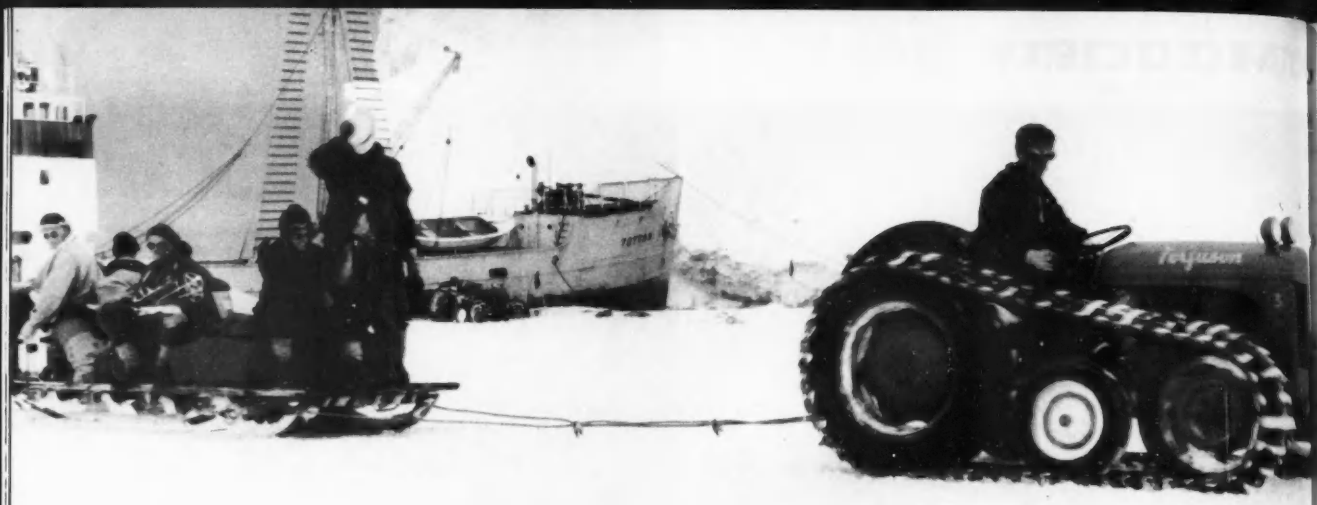
Prof. A. L. Hodgkin
Physiologist

Sir Alfred Pugsley
Engineer

Prof. R. J. Pumphrey
Zoologist

Dr H. W. Thompson
Chemist

Prof. J. Z. Young
Zoologist



As an outstanding example of one of its recent contributions to science, the Royal Society organised a major expedition to the Antarctic during the IGY. Here a tractor is towing a sledge-load of personnel from Halley Bay towards the base site, Royal Society Base. M.V. *Tottan* is moored in the background.

industry and the amateur astronomical and radio organisations. Taking advantage of an offer made to the ICSU Special Committee for Space Research (COSPAR) British satellite instruments are to be launched from a U.S.A. rocket known as *Scout*; the first is due to be launched towards the end of 1961. The preparations for this and other aspects of the British programme are being most actively pursued at present.

Since the Society's foundation prominent among its activities has been the conduct of international relations with men of science throughout the world. In the present century the Society has taken a leading part in the affairs of ICSU and its predecessors, the International Association of Academies and the International Research Council. Its Fellows, Sir Henry Lyons, Prof. F. J. M. Stratton, Prof. A. V. Hill, and Sir Harold Spencer Jones have successively acted as Secretary to these bodies and Sir Rudolph Peters, F.R.S., is currently President of ICSU, the next General Assembly of which the Royal Society will warmly welcome in London in September, 1961.

In addition to co-operating with ICSU, the Society has direct relations with Academies of Sciences throughout the world and has taken a leading part in the development of post-war scientific relations, notably with the U.S.S.R. Academy, with which the Society has an exchange arrangement for lecturers and research workers. The Society also has a Committee, supported by several advisory panels, for co-operating, through the United Kingdom National Commission, in the natural sciences programme of Unesco. The Society's Foreign Secretary is chairman of the Society's Unesco Committee as well as the Society's International Relations Committee.

Some measure of the Society's activity in international relations can be gauged from the fact that its Council is advised by 50 committees, sub-committees and panels, on which sit representatives of 83 different national scientific bodies and which have a total membership of about 800 persons.

ADMINISTRATION OF PARLIAMENTARY GRANTS-IN-AID

It was in 1849 that Her Majesty's Government first proposed to make a grant of £1000 a year for the promotion of scientific inquiries and invited the Royal Society to assist it. Requests to administer other Government grants have been received since and, in addition to administering a Parliamentary Grant-in-Aid for international relations (£42,500 for this year) on the advice of its National Committees, the Council administers a Parliamentary Grant-in-Aid for Scientific Investigations (£75,000 for this year) and a Parliamentary Grant-in-Aid for Scientific Publications (£10,000 for this year) and libraries' Assistance (£2000 for this year). Council is assisted in this by nine boards, eight advise on allocations for scientific investigations and one for both publications and libraries' assistance. The membership of each is very carefully selected so that the best opinion on the applications can be obtained on all subjects.

For investigations financial support is restricted to the supply of special apparatus or to helping scientific expeditions. The Society is anxious to encourage expeditions of high scientific quality and has recently appointed an expeditions officer to assist in this. Eighty projects received help last year, of which about twenty were expeditionary investigations, the others being mainly, but not exclusively, for projects at universities. These boards meet three times each year and provide an excellent means of expert scrutiny of applications. Their activities frequently go well beyond scrutiny and many research workers have had much valuable guidance as a result of applying to the Royal Society. Compared with amounts now available through Government agencies for the support of scientific research, the grants allocated on the advice of these boards is relatively trivial and it seems a pity that in the national interest the money handled by the boards is not commensurate with the efficiency and expertise which is provided by this finely tuned grant-giving machinery first created as long ago as 1888.

The main concern of the Scientific Publications Board is to help scientific societies to overcome financial difficulties in the publication of original scientific work. Its current policy is to

help publishing societies to help themselves in balancing their publication accounts and it has been of considerable assistance in bringing about the present healthy state of publication by scientific societies in this country. The small grant for libraries is principally to help scientific societies whose library holdings have fallen into a state of disrepair. Seventeen grants for publication and one for a library were made last year.

OTHER PUBLIC RESPONSIBILITIES

Apart from those mentioned above the Society has been called upon to render many public responsibilities. Thus Queen Anne appointed the President and Council to be "the constant visitors" of the Royal Greenwich Observatory and the Society is a custodian of one of the four copies of the Imperial Standard Yard and Pound. The Society's Council has accepted invitations to nominate representatives to eighty institutions and other bodies and over one hundred of its Fellows act in this capacity. These bodies include university courts, the board of governors of public schools, government committees and scientific organisations of many different kinds. The President is, *ex officio*, a trustee of the British Museum, The Times Publishing Co. Ltd ("Committee of Trustees"), the Spectator Committee and a number of other Trusts. Acts of Parliament require all appointments to the Medical, Agricultural, and the Scientific and Industrial Research Councils, and some other governmental research committees, to be done in consultation with the President of the Royal Society.

Since the foundation of the National Physical Laboratory, a scheme for which was drawn up by the Society and H.M. Treasury in 1899, the Society has appointed the General Board and the Executive Committee of the Laboratory, and the Society is still responsible for its scientific programme. The financial responsibility for the Laboratory was transferred to the Department of Scientific and Industrial Research in 1918.

THE SOCIETY'S PUBLICATIONS

Although the Society has these wide-ranging activities, its principal purpose is that of a learned society. Doubtless the Society has been asked to undertake these additional responsibilities because it has been very successful in discharging its learned society functions of disseminating new knowledge. Nevertheless, the other activities are within its chartered purpose of improving natural knowledge and would otherwise not have been undertaken.

In 1665 the Society's Secretary, Henry Oldenburg, started the *Philosophical Transactions of the Royal Society*. This is the senior scientific journal in the world and is now issued in two series: Series A (mathematical and physical sciences), and Series B (biological sciences). Each part consists of a single paper or monograph and last year, despite the printing industry dispute, 14 parts were issued in Series A and 11 in Series B. Shorter papers are published in the *Proceedings of the Royal Society*, also in two series. Last year 20 parts in Series A containing 195 papers and 7 parts of Series B containing 62 papers were published. The highest standard of scientific content and of presentation are maintained through a rigid system of refereeing by the Fellows. The communicator of a paper must be a Fellow and he has the primary responsibility to ensure that the Society's high standards are complied with. With the aid of the sectional committees the Physical and Biological Secretaries then supervise further assessment before acceptance. Prompt publication is a ceaseless endeavour of the Society. The printing, also to high standards, is done by the Cambridge University Press.

Although not quite so well known, the Society's other regular publications also make important contributions to the literature of science. Once each year "The Biographical Memoirs of Fellows of the Royal Society" provide a book written by leading men of science about their erstwhile colleagues, all of whom have made significant contributions to the advancement of science. For instance, in the current volume Sir Robert Robinson is the author of a memoir on Sir John Simonsen, Sir Christopher Hinton of one on Sir Claude Gibb, and Prof. William Wilson on Sir Owen Richardson. Twice a year there is issued a part of *Notes and Records of the Royal Society* currently edited by Sir Harold Hartley. A recent part consisted mainly of authoritative articles on Charles Darwin and it has been described as one of the best of the tributes appearing on the occasion of the centenary of the publication of "The Origin of Species". A special volume of *Notes and Records* dealing with the founders and origins of the Society is being prepared for issue at the time of the Society's Tercentenary Celebrations. It will provide a new evaluation of the founders and their times and will be at the same time intrinsically interesting and historically valuable. It will also be available as a book entitled "The Royal Society—Its Origins and Founders".

Another annual publication is the "Year Book of the Royal Society" which not only contains the Annual Report of Council but an up-to-date list of Fellows, membership of committees, medal awards, and lecture appointments. It also gives details of the Society's funds and its research appointments, together with annual reports from holders of these appointments.

On the advice of its Mathematical Tables Committee the Society publishes a series of "Mathematical Tables" and three new volumes on "Representation of Primes by Quadratic Forms," "The Riemann Zeta Function," and "Bessel Functions part III—Zeros and Associated Functions" are planned to appear this year.

It is particularly fitting that the first volumes of "The Correspondence of Isaac Newton" are to be issued in the Society's tercentenary year. These constitute a scholarly tribute to the Society's greatest Fellow. Volume I has appeared and volumes II and III are to follow shortly. These first three volumes representing years of painstaking endeavour have been edited by Prof. H. W. Turnbull, F.R.S., who, owing to ill health, is unable to continue as editor for the projected remaining four volumes, of which Dr J. F. Scott has been appointed editor. Happily Prof. Turnbull's services will continue to be available as a consulting editor.

In June, 1957, the Society issued "The United Kingdom Contribution to the International Geophysical Year" and has in active preparation a four-volume work reporting the observations made at the Royal Society Base, Halley Bay, the Society's IGY Antarctic station.

THE SOCIETY'S MEETINGS

Discussion of new scientific discoveries is also an important part of the dissemination of new knowledge and for 300 years it has been the Society's custom to meet once a week "in tearme time". The Society continues to do so on Thursdays about twenty-three times each year. Some formal business precedes the scientific business which takes the form of the reading of papers on contemporary research, a lecture on a research institution or one of the named lectures of the Society, namely, the Croonian lecture (first delivered in 1738) on a biological subject, the Bakerian lecture (founded in 1775) on a physical science subject, the Ferrier lecture in neurophysiology, the Leeuwenhoek lecture in microbiology, the Wilkins lecture in the history of science. These named lectures provide an excellent means of providing reviews in important scientific topics. On about four occasions each year discussion meetings, each of one or two days' duration, are organised by a Fellow by invitation of the Council on a topic which is ripe for such treatment. Those taking part are leaders in the subject field and frequently include scientists from overseas. Recent topics have been Problems of Stellar Evolution, the Biology of the Southern Cold Temperate Zone, Space Research, and the Results of the Royal Society IGY Expedition in Antarctica. Reports of these appear in the *Proceedings of the Royal Society* and so are available to a wider audience than is able to assemble at Burlington House. In arranging its meetings, the Society does not restrict itself in its choice of speakers, which is made from the whole world of science. This year, for instance, the Croonian lecture will be delivered by Dr André Lwoff of the Institut Pasteur in Paris and the Bakerian lecturer is Dr Gerhard Herzberg of the Canadian National Research Council. Twice each year, in May and in June, the Society has a conversazione at Burlington House. During these evening receptions experiments and films are shown by Fellows and others to present current developments. Representatives of the Press attend a special Press view of the May conversazione and some 300 boys and girls from schools also inspect the demonstrations the day following this conversazione.

THE SOCIETY'S HOUSE

The Society's accommodation is provided free, since 1780, by H.M. Government and it took up its present quarters specially constructed for the Society's use in Burlington House in 1873. The Society's library of 150,000 volumes is housed here. It contains many rare books and long runs of periodicals, principally those of sister national academies of sciences. In the library are collected the works of Fellows who are each encouraged to send reprints of his or her papers and books as well as recordings of his or her voice. The Society's policy is co-ordinated with that of the neighbouring scientific societies in Burlington House and no attempt is made to duplicate the specialist holdings of our neighbours. There is, however, an excellent collection of mathematical books and periodicals.

Among the Society's treasures held at Burlington House is the Society's Mace and Charter Book, both of which were gifts of King Charles II who inscribed the Book and described himself as founder. All Fellows formally admitted by the President since then have signed the Book, incidentally making it one of the finest existing autograph records of distinguished men and women. A former Assistant Secretary, C. R. Weld, said of the Mace ". . . the associations appertaining to it, embracing the remembrance that around it have been gathered men whose names not only shed imperishable lustre on the Royal Society but on the civilised world, must hallow it to all lovers of science and truth." Both the Mace and the Charter Book are in use today. The Society is also the proud possessor of the manuscript of Newton's "Principia," of which Laplace wrote ". . . (it) is pre-eminent above any other production of human genius." Also at Burlington House is the reflecting telescope made by Newton's own hand in 1671. Adorning the walls are many fine portraits of Fellows and other distinguished scientists. Many of these are by distinguished artists and this year it is intended that there shall be added Sir Gerald Kelly's portrait of Sir Cyril Hinshelwood, O.M., P.R.S.

In addition to the Library, the Meeting Room and its anteroom where Fellows and others foregather before the Thursday meetings, the Society's house provides accommodation for committee meetings, which sometimes take place at the rate of several each day, and the majority of the Society's staff of about sixty persons. With the increasing demands made on the Society and the consequent increase in staff, the Society has long since outgrown its present accommodation and more room is an urgent necessity. As a temporary measure part of the staff at present occupy the premises formerly used by the British Association in Burlington House and part is located at 11 Clarence Terrace in Regent's Park. Further accommodation has been promised to relieve the present difficulties. Management costs and extra staff have placed greater demands on the Society's finances but a Tercentenary appeal for funds made to industrial organisations and to the Fellows to provide principally for such costs and others necessary to maintain the Society's advancement has met with an excellent response, almost £370,000 being gifted to the Society to meet such expenditure over the next ten years. There are, however, other areas of activity, for example, in international relations where the Society could be more effective if funds were available.

FORWARD TO A FOURTH CENTURY

It is hoped that the foregoing survey of the Royal Society today shows it to be as vigorous as it ever has been in improving natural knowledge. The Fellows of the Society, by seeking excellence in all the different aspects of the Society's endeavour to promote scientific advance—its publications, its meetings, its committee work, its awards and appointments—not only achieve much by themselves but also, by example, encourage others elsewhere to do the same. The intention of so many distinguished scientists from the whole world of science to be present at the Society's Tercentenary Celebrations in July this year and the way in which national institutions are likewise proposing to pay tribute is a great encouragement to continue into a future which we hope will make its Fellows equally honoured to be heirs to the great tradition which is the pride of the present-day Fellows of the Society.

SCIENCE AND MOUNTAINEERING

RONALD W. CLARK

In becoming the handmaiden of science, a sport which was once suspect has led to such advances as the development of the glacier theory and the study of man at high altitudes.

The link between scientific inquiry and mountain climbing began with Leonardo da Vinci's wonder at the world above the snowline and has culminated in the work of the Medical Research Council, the Ministry of Supply, and the Royal Aircraft Establishment at Farnborough which helped to put Hillary and Tensing on the top of Everest in 1953. The connexion survived the continuing dialectical battle between those who climbed mainly to observe and those who climb mainly "for fun". And *The Alpine Journal,* the first as well as the most distinguished of all alpine periodicals, still retains as its sub-title "A Record of Mountain Adventure and Scientific Observation".

Leonardo, whose "large mass of ice formed by layers of hail" may well have been a glacier, and who is now thought to have reached 10,000 ft. near the Col d'Ollen, was a lonely figure, ahead of his time both as mountaineer and as scientific thinker. So, too, were Conrad Gesner (1516–65), the "German Pliny" credited by Cuvier with being the creator of scientific botany and the founder of zoology, and Josias Simler (1530–76) who followed Gesner into a professorial chair at the University of Zürich. Gesner resolved "to ascend several mountains, or at least one, every year, when the flowers are in their glory, partly for the sake of examining them and partly for the sake of good bodily exercise and of mental delight".[1] Parts of Simler's "De Alpibus Commentarius", published in 1574, formed the first practical handbook on movement above the snow-line, and one which showed that its author understood the use of rope, alpenstock, crampons, and dark glasses.

THE FIRST MILESTONE

It was, of course, the line of permanent snow and the glaciers which lay above it, that first attracted scientists. The *Philosophical Transactions* of the Royal Society,[2] published in 1669, a letter to Theodore Haak from a Bernese doctor on "the Icy and Chrystallin Mountains of Helvetia call'd the Gletscher". In 1685 Bishop Burnet wrote to Boyle of the "One Hill not far from Geneva, called *Maudit* or Cursed", and some fifty-five years later Windham and Pococke visited Chamonix, a visit which produced a paper for the Royal Society[3] on the glaciers around this same Mont Maudit, or Mont Blanc as it was later called.

To investigate these in more detail it was necessary to enter a new world and to reach heights which Western man had never yet attained. Yet it was only in 1760 that Horace Benedict de Saussure, the Genevese naturalist, produced the first important combined mountaineering and scientific milestone with his offer of a reward for anyone who found a way to the top of Mont Blanc; it was twenty-six years before the local doctor Paccard and the guide Jacques Balmat succeeded, and twenty-seven years before Saussure himself stood on the top of Mont Blanc accompanied by

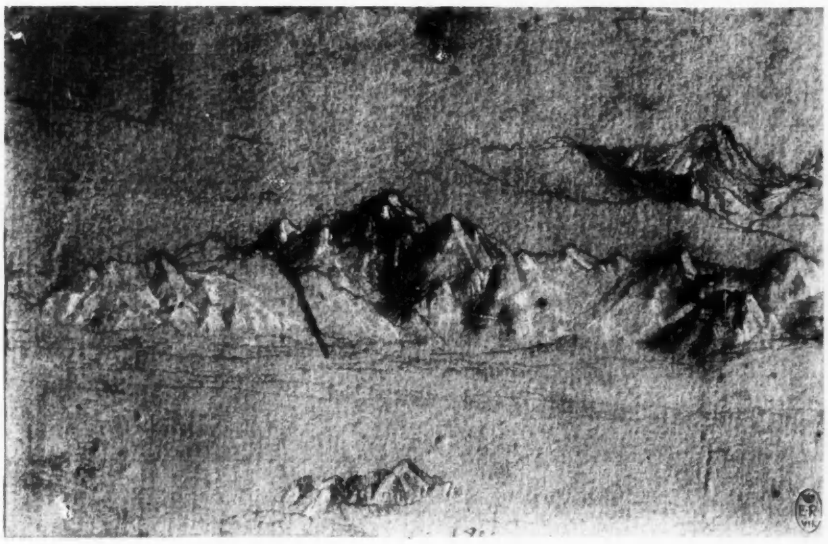


FIG. 1. "Mountain Chain", by Leonardo da Vinci.
(From the Royal collection at Windsor, reproduced by gracious permission of H.M. the Queen)

FIG. 2. Horace Benedict de Saussure, F.R.S. (1740–99), Member of the Royal Academies of Science of Paris, Turin, and Stockholm, the Genevese naturalist whose offer, in 1760, of a reward to anyone who found a way to the top of Mont Blanc, led to the exploration of the mountain. He himself made the third ascent of Mont Blanc on August 3, 1787, roughly a year after the first ascent had been made by Dr Michel Paccard and the guide, Jacques Balmat, both of Chamonix. Balmat and two other guides made the second ascent in July 1787.

his valet and eighteen guides. The Genevese, testing the boiling-point of water at 15,782 ft., taking the temperature of the snow and the pulses of his guides, spending three and a half hours on the summit in a long series of carefully thought-out scientific experiments, ushered in a century of scientific investigation above the snow-line that was to concentrate for many years on glaciology and geology.

Saussure himself travelled extensively, spent seventeen days camping out on the 11,060 ft. Col du Géant, and recorded his "Voyages dans les Alpes". He was followed by Louis Agassiz (1807–73), James David Forbes (1809–68), Prof. Tyndall (1820–93) and T. G. Bonney (1833–1923), to name only four of the more prominent men who came to the Alps as scientists and remained as mountaineers.

These investigators, and many more, marked and measured and theorised, so that by the last third of the century, and after some of the most bitter scientific controversies of the period, the principles of modern glacier theory had been formulated. But these early mountain-scientists had not only to carry out weary and sometimes dangerous experiments in difficult conditions; they had to learn how to move in safety above the snow-line. It was such men—particularly Forbes, the first Honorary Member of the Alpine Club—who accumulated the knowledge later inherited by the mountaineers of the "Golden Age", an era usually taken as starting with Wills's ascent of the Wetterhorn in 1854 and ending with Whymper's ascent of the Matterhorn in 1865.

Agassiz built on the Unteraar Glacier his "Hotel des Neuchâtelois", a rude rock-encampment where he and his companions bivouacked for weeks on end. Forbes trained the guide, Auguste Balmat, and helped to create a new generation of men who would be more than mere "pointers-out of paths" and who would understand at least the mechanics of scientific observation. Bonney "opened up" the Dauphiné and carried out a unique series of Alpine excursions while collecting the material for his "Building of the Alps". Tyndall, engaged in the most bitter of glaciological controversies while gaining giant stature as a mountaineer, made three ascents of Mont Blanc for scientific purposes and spent twenty hours on the summit on the last of them. He climbed Monte Rosa with a flask of tea and a sandwich; in 1862 he went higher than any man on the Matterhorn; and he epitomised the way in which scientific investigation and mountaineering became inextricably mingled during the 19th century.

This was true, moreover, of amateur observers as well as of professionals. The "Suggestions for Alpine Travellers", written by John Ball, the first President of the Alpine Club, for the first volume of "Peaks, Passes, and Glaciers"—that forerunner of *The Alpine Journal*—contained details of how the ordinary traveller might make "observations connected with general Physics and with Glacier Phenomena, as well as with Geology and Natural History."

CLIMBING IRONMONGER

Francis Fox Tuckett, mountaineer first and amateur scientist second, was typical of such travellers with his elaborately organised notebook; a man who climbed his mountains "hung from head to foot with 'notions' in the strictest sense of the word, several of them being inventions of his own. Besides such commonplace things as a great axe-head and a huge rope and thermometers, he had two barometers, a sympiesometer, and a wonderful apparatus, pot within pot, for boiling water at great heights, first for scientific and then for culinary purposes."[4]

There was even a suggestion that the Alpine Club itself might form a scientific recruiting ground, and John Ball wrote to Tyndall when inviting him to become Vice-president, saying that "Many men (originally mere climbers) are beginning to take an interest in the physical questions that have to be decided in the Alps. In a few years there will be an organisation which you will be able to wield with effect."[5]

It is true that science helped to give respectability to what was still a suspect sport. But there was a reaction to scientific evangelism. It culminated in Leslie Stephen speaking at the Club's Winter Dinner of 1861 and giving a mock-heroic account of a climb. He poked fun at the scientists after the manner of a famous passage in his "Playground of Europe". " 'And what philosophical observations did you make?' will be the inquiry of one of those fanatics who, by a reasoning process to me utterly inscrutable, have somehow irrevocably associated alpine travel with science. To them I answer, that the temperature was approximately (I had no thermometer) 212 degrees Fahrenheit below freezing point. As for ozone, if any existed in the atmosphere, it was a greater fool than I take it for." Tyndall,

incensed at the jibe, resigned from the Club—only to be received back into the fold in 1887 as a distinguished Honorary Member.

By this time fresh links were beginning to bind mountaineering and science. For as the world above the snow-line became better known the gaps in geological and glaciological knowledge became less numerous. Interest turned to the use of high mountains as meteorological observatories, and to the physiological problems of the greater heights into which man was now beginning to venture. And it is here, before the turn of the century, that the modern era of collaboration between science and mountaineering may be said to begin.

From 1880 onwards, the Swiss Alpine Club had sponsored the erection of meteorological instruments on or near various summits. As the last decade of the 19th century opened, the Vallot observatory was erected at about 14,000 ft. on Mont Blanc—permission being given by the local authorities only on condition that Vallot also built a second hut for the use of climbers—and was followed four years later by the Janssen observatory, built virtually on the summit itself. Vallot's observations between 1893 and 1898 were published in Paris, but Janssen's observatory, built on a foundation of snow and ice, had an unhappy history and was dismantled after a few years.

In parenthesis, it may be noted that neither of the two Mont Blanc observatories provided such a long list of results as that which came from the building opened on Ben Nevis in 1883. Together with an observatory at sea-level, and a hut for observation half-way up, the Ben Nevis station provided a vast mass of useful information until it closed in 1904—for want of a Treasury grant of £350 a year.

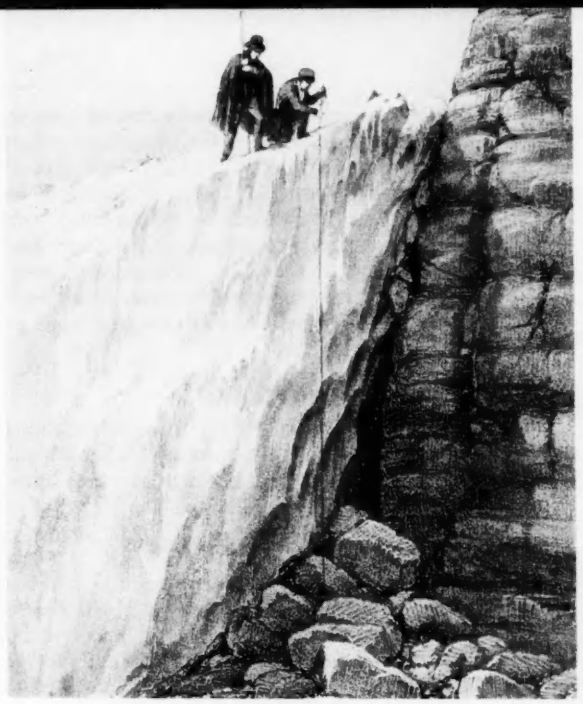
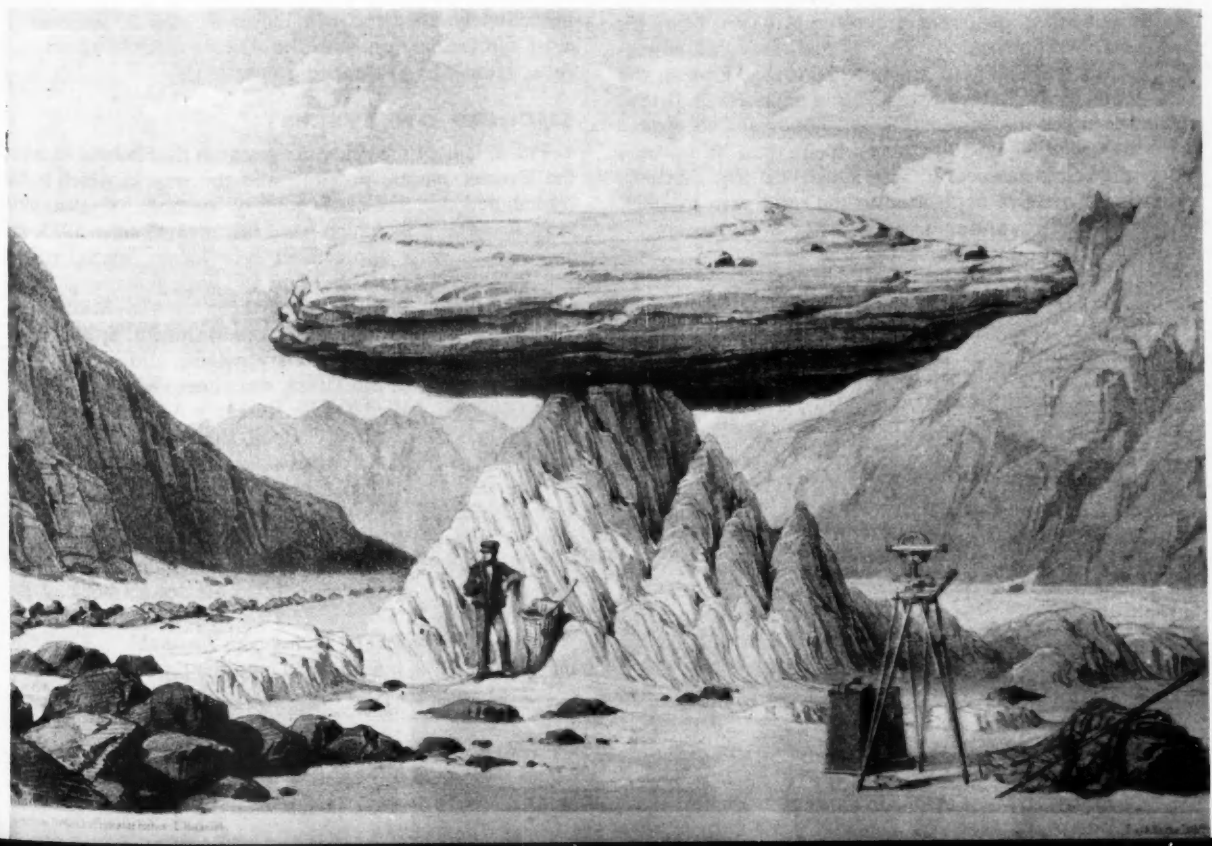


FIG. 3 (*above*). Forbes and his guide, Auguste Balmat, measuring the height of the ice at one point on the Mer de Glace, where much of Forbes's most important work was carried out.

FIG. 4 (*below*). Forbes's survey equipment on the Mer de Glace, seen beside a glacier table. Much of his work involved inserting wooden pegs into the ice and taking a record of their movement during the following years.



The Mont Blanc observatories were the first of a number to be set up in the Alps, perhaps the most famous being that on the Jungfraujoch, 11,000 ft. up and served by the railway that was completed in 1912. The detailed meteorological—and sometimes astronomical—observations which could be made from such high vantage points were important to the marriage of science and mountain-exploration. But they were soon overshadowed by the observations which could be made on the human frame itself as it was pushed to ever greater heights.

MAN AT HIGH ALTITUDES

Until the conquest of Mont Blanc towards the end of the 18th century, many thought it impossible that a human being could survive a night spent out high above the snow-line, or that he could breathe at all at the height of the summit of Mont Blanc. The events of the following century showed, however, that the human frame was far more adaptable to the rarefied air of high altitudes than had been supposed; but they left unsolved the riddle of the greatest height which man could attain. It was this object, together with its allied physiological problems, which received increasing attention from the 1890's onwards, and it is the one which still most closely links the interests of mountaineers and scientists.

Thomas Woodbine Hinchliff, one of the original members of the Alpine Club, had written in 1876 that those with experience "agree that 21,500 ft. is near the limit at which man ceases to be capable of the slightest further exertion".[6] Three years later Edward Whymper set out for the Andes, returning to Britain the following year with detailed accounts of his experiences at altitudes up to 18,500 ft., with valuable collections of rocks and insects gathered at great heights, and extensive scientific records that he published in a separate volume dealing with his expedition. Martin Conway, later Lord Conway of Allington, reached the 22,600 ft. summit of Pioneer Peak in the Karakoram in 1892, on an expedition planned so that it enabled him "to make scientific collections and to engage in all the scientific investigations which could be pursued under the circumstances". The Duke of the Abruzzi, organising a massive expedition to the same area in 1909, did much the same, and returned with a quantity of information.

From the turn of the century, in fact, most major expeditions to the Himalayas, or to any other range whose peaks rose above 20,000 ft., were planned so that detailed observations could be taken of the physiological effects of altitude; and, from 1921 onwards, of the effects of breathing oxygen carried in cylinders.

It is here, with the introduction of oxygen, that an almost contemporary impression is first given. Shortly after the end of the First World War, the Oxygen Research Committee of the Department of Scientific and Industrial Research, and Prof. J. B. S. Haldane, had supported Dr Alexander Kellas in a number of experiments with oxygen which he had made on the lower slopes of the Himalayas. Further experiments, planned for the reconnaissance of Everest which took place in 1921, were to form the most important scientific work of the expedition. Kellas died, however, on the long trek across the Tibetan plateau, and no one else in the party had the experience needed to continue this part of his work.

On the 1922 and the 1924 expeditions, however, experiments were made with various forms of oxygen apparatus and Haldane, speaking at the British Association meeting in 1926, said that the new physiological facts elicited were of the most striking character.

By this time, scientific research not only played a definite part in most expeditions—where organisers saw to it that someone of experience collected the necessary samples and specimens. It was, in fact, helping men to reach greater heights, more efficiently, and in greater safety. This was true not only of investigations into the use of oxygen—a subject on which mountaineering opinion was, and is, divided, since it is the most artificial of all artificial "aids"; it was true, also, of careful scientific research into the best diet at high altitudes, of the wind- and cold-resisting properties of various materials and, perhaps as important as anything else, of the scientific design of boots.

All these matters were reflected in various appendices to the expedition books that appeared during the years before the Second World War, and in the descriptions of how manufacturers had used their research resources to produce the articles required. The higher mountains became, in fact, laboratories where manufacturers of scores of products, from photographic films to concentrated foods, could have their goods tested under exceptional conditions. It was a happy development, usually useful to both sides in terms both of experience and of hard cash.

This marriage between mountaineering and applied industrial research was only just celebrated when the outbreak of war effectively stopped mountain climbing and diverted research into other channels. It was renewed immediately after the war, however, and it achieved its most spectacular results in the success of Colonel (now Sir John) Hunt's Everest expedition of 1953.

SUCCESS ON EVEREST

The extent of the scientific research that helped to make the Everest success possible, and the way in which it has contributed to the extraordinary number of successful Himalayan ascents which have taken place since 1953, are not perhaps fully appreciated even today. Special fabrics were devised for the expedition and were given wind-tunnel tests for wind- and rain-resistance at the Ministry of Supply's physiological research establishment. Special high-altitude boots of a revolutionary pattern, and involving the use of tropal to aid insulation, were designed by the British Boot, Shoe and Allied Trades Research Association.

The Medical Research Council, the Admiralty, the Polar Institute, the Royal Aircraft Establishment at Farnborough, and the Electro-Medical Research Unit were only some of the organisations whose research facilities were used, in one way or another, to help solve problems of cold, oxygen-lack, or nutrition—all subjects, incidentally, which were later dealt with in an appendix to Sir John's book of the expedition, and in an article by Dr Griffith Pugh, a member of the expedition, in *The Himalayan Journal*.[7]

Oxygen was, of course, used, and the problem of whether

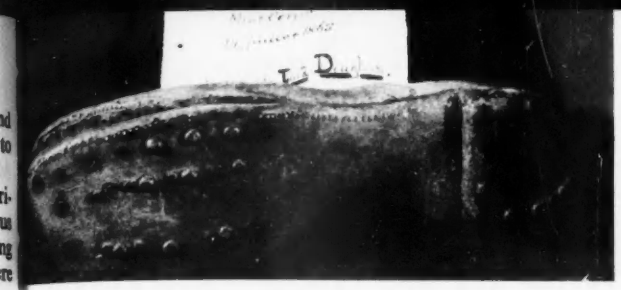
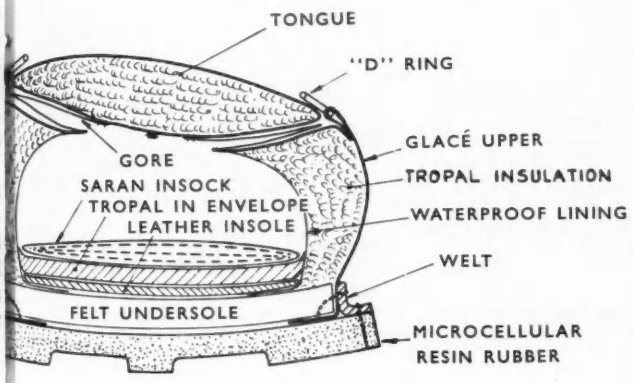
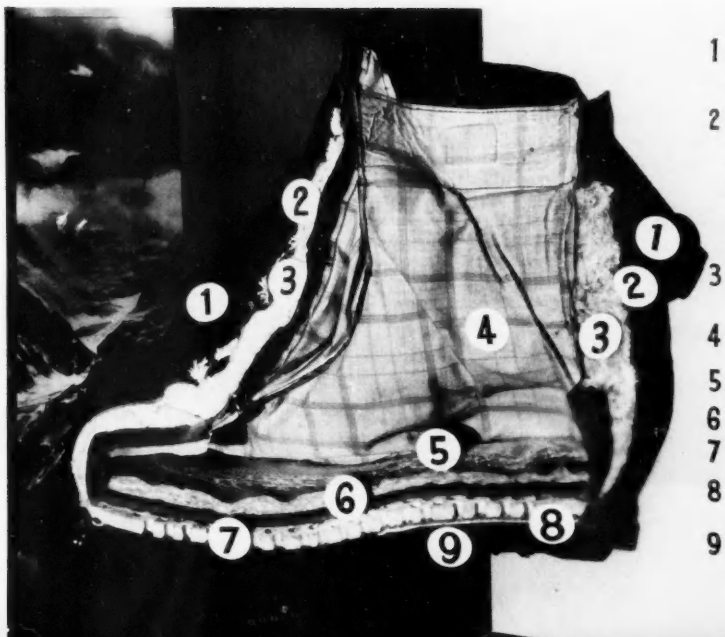


FIG. 5 (*above*). A shoe from the body of a climber killed in the great Matterhorn accident of 1865—the nailing apparently being entirely of hobs. The first ascent of the Matterhorn, at the time the most important unclimbed summit of the Alps, was made on July 14 by a party of seven led jointly by the Rev. Charles Hudson and Edward Whymper. After a successful ascent, a slip occurred during the descent, and three of the amateurs and one of the guides fell to their deaths. Edward Whymper and two of the guides were saved only by the snapping of a rope. The accident, one of the worst that had then happened in the Alps, had a considerable influence on public reaction to mountaineering, *The Times* publishing a famous leading article which asked of the sport: "Is it life? Is it duty? Is it common sense? Is it allowable? Is it not wrong?"

FIG. 6 (*right*). Varying forms of footwear on the 1922 Everest expedition. Somervell, third from left, is wearing a primitive form of (apparently wool-lined) high-altitude boot.



FIGS. 7 (*above*) and 8 (*right*). A section through the special Everest boot designed by the British Boot and Shoe Allied Trades Research Association for the successful 1953 Everest expedition.



1 DETACHABLE WATERPROOF COVER

2 GLACÉ KID UPPER, BACK SPRAYED WITH LATEX AND OUTER SURFACE TREATED WITH SILICONE DRESSING TO IMPROVE WATER RESISTANCE.

3 HEAT INSULATION 6 LAYERS OF KAPOK ('TROPAL')

4 WATERPROOF INNER SKIN

5 VINYLIDENE (TYGAN) INSOCK

6 LEATHER INSOLE

7 PERFORATED FELT UNDERSOLE

8 HANDSEWN REVERSED WELT (LEATHER)

9 SPECIAL MICRO-CELLULAR RUBBER SOLE (DUNLOP RUBBER CO. LTD.)

or not man can reach the highest point on earth without its aid—even when he has the benefit of light-weight clothing and equipment—is still open. It seems inevitable that at some height all a normal human being's muscular powers are needed for breathing, and that at that point the loss of body heat in the exhaled breath is such that death by freezing is unavoidable; and the height, curiously enough, appears to lie around the 29,000 ft. level which is roughly the height of Everest.

One interesting point is the number of synthetic materials used on the Everest expedition and now generally adopted by mountaineers. Nylon for the inner linings of clothes, microcellular rubber for boot-soles, tropal as the meat in the sandwich which formed the uppers, and Alkathene containers which carried out such useful tasks as keeping sleeping bags dry—these were only some of the special materials built by scientists so that they had certain specific properties which natural products lacked.

It is easy to see here the latest lines along which the alliance between mountaineering, science, and technology is developing. There came first the physical investigation of the world above the snow-line and the development of glacier theory. Then followed the use of mountains as high observation platforms for the astronomer or the meteorologist, and then as the territory where the effects of altitude and cold on the human frame could be conveniently studied. And there has followed the use of the mountaineer as a form of mobile test-rig which can be used to try out the newest products of modern technology. In many ways this development is a repayment to the mountaineer for the part which he has played, unconsciously or otherwise, in aiding science during the past two centuries.

For it must be remembered that the day of the mountaineer of independent means is now virtually ended—such men as Conway, who expected a K.C.S.I. for his Himalayan journey . . . "the number for the year was made up without me and I was offered an ordinary knighthood as a stopgap," he later wrote. "It served me well enough".[8] In more proletarian times the careful recording of research results is a small price to pay for supplies of clothing, equipment, food, and photographic material.

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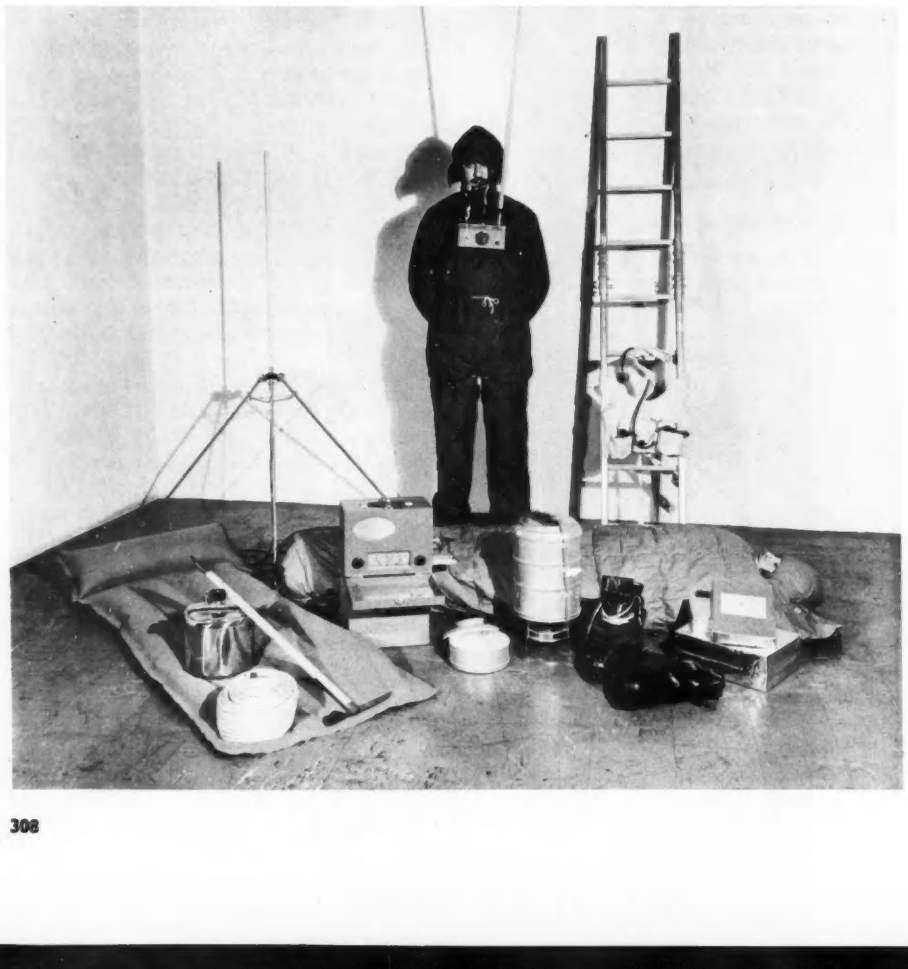


FIG. 9. Some of the special equipment designed for use on the 1953 Everest expedition. The special high-altitude boots designed for the expedition—and tested in the cold chamber at RAE Farnborough—are seen front right.

GEOPHYSICS AND SPACE RESEARCH

By ANGELA CROOME

Geophysics and The Royal Society

This month the Royal Society celebrates the tercentenary of its foundation under Charles II. While offering our hearty congratulations on this occasion it seems appropriate to recall some of the enterprises supported by the Royal Society that have particularly furthered geophysics and the earth sciences. This interest has an honourable place in the Society's history and is almost as long-lived as the institution itself. It was Edmund Halley, the first secretary, who made the first magnetic survey ever undertaken at sea. This was followed by his publication in 1700 and 1701 of the first world-wide magnetic charts. He might, in a sense, be called the grandfather of the International Geophysical Year, for the work he started led directly to the need for simultaneous world-wide study of geomagnetic problems that provided the incentive both for the First and Second Polar Years, and from these, the much expanded version of the same plan, the IGY, stemmed. Now the Royal Society is deeply involved in the plans for making a thorough new world magnetic survey during the coming sunspot minimum in which many of the IGY countries are co-operating.

It was Capt. Cook's first voyage to the South that aroused the Society's interest in Antarctica. He sailed with a Royal Society commission in his pocket when he set forth on his second expedition in 1772 which was to make the first circumnavigation of the Antarctic Circle and to establish that the *terra incognita australis*, if it existed at all, was not the gorgeous "earthly paradise" posited by most geographers since the early Greeks. The Society's active and continuing interest in this strange and fascinating area which tantalisingly seems to offer the key to so many geophysical puzzles, has persisted from that period. Perhaps its full harvest of information is yet to come; perhaps this will result from the current intensive study which the Society is heavily supporting through SCAR. But the present state of knowledge is deeply indebted to two major scientific expeditions of the last hundred years which the Society sponsored, the *Challenger* cruise in Southern waters in 1872–6 and Scott's first expedition of 1901 which opened up the route to the Pole and established access to the interior for so many of the expeditions that have followed.

The tercentenary falls at a time when the Society is testing out its tradition of support for pioneering research in a new field—that of space; one which Newton would certainly have embraced but had not the remotest chance of pursuing. This will undoubtedly prove more productive of knowledge about the physical nature of our environment than any of the previous fruitful geophysical enterprises the Society has supported. It is a fitting subject to be closely associated with the Society in its tercentenary year.

Pioneer V and the Solar System

Data obtained during the first month in orbit of *Pioneer V* (the American space probe launched towards the orbit of Venus on March 11) have been assessed and the preliminary interpretation presented at the American Geophysical Union Meeting in Washington on April 29. The three main conclusions to be drawn from the magnetometer measurements alone are of the greatest significance. Taken together with those from the other experiments, one can say with confidence even at this early stage of data reduction that the *Pioneer V* experiments promise to revolutionise knowledge of the solar system and the large-scale physical mechanisms that operate within it.

The period during which the probe's instruments were at their prime and there was full and convincing telemetry recovery, coincided with one of the most varied and active sequences of solar-terrestrial events than can ever have fallen within a bare two months' span. The following account deals only with the most exciting results of the first month's material, that is from March 11 to April 5. The main instruments continued to operate fully satisfactorily at least till the middle of May. Useful data may be expected for some time thereafter, but there was evidence then that the chemical batteries aboard the vehicle were beginning to fail and the strain on them was progressively increased after the probe had passed the 8-million-mile point when the switch was made to the high-power radio transmitter. The vehicle was, of course, still drawing away and therefore still increasing the radio distance to be bridged.

During the latter part of March the relatively quiet condition on the Sun that had characterised the period immediately after the probe was launched gave way to conditions of violent solar activity. Numerous flares of various sizes, large loops and prominences, and radio noise-bursts were all observed on the Sun. Much of this activity was associated with the appearance of a plage region near the central meridian of the Sun's visible disc, on April 1. During the same excited period a large Forbush type decrease occurred in the galactic cosmic radiation. From the point of view of experimenters concerned with cosmic and other radiation measurements, this sequence of events was so fortunate and so rare as to seem almost miraculous. Since then an even more unusual event has taken place and presumably been monitored by *Pioneer V*, a large cosmic ray intensity increase which was well observed over the U.S. in early May.

The three main conclusions that have been drawn from the **magnetometer measurements** made between March 11 and April 5 and instrumented by the Space Technology Laboratories, California, are as follows:

1. Ring-current at 10 Earth-radii. *Pioneer V*'s magnetometer readings confirmed the presence of a disturbed field in the region between 6 and 13 Earth-radii. These were first observed by *Explorer VI*, the "paddlewheel" satellite launched last autumn. The assumption that this perturbation is due to a hydromagnetic ring-current circling the Earth is consistent both with the readings from both *Explorer VI* and *Pioneer V* (each sampling a different region of space). Such a ring-current had been postulated for over half a century. The ring-current appears to be a magnetically "quiet day" phenomenon. It flows in the westward direction and reaches its greatest

amplitude, calculated as about 5 million ampères, at 10 Earth-radii. The current is 6 Earth-radii thick, that is, extends out from 7 Earth-radii to 13 radii, subtracting from the Earth's field on the inward side of the ring and adding to it on the outward side.

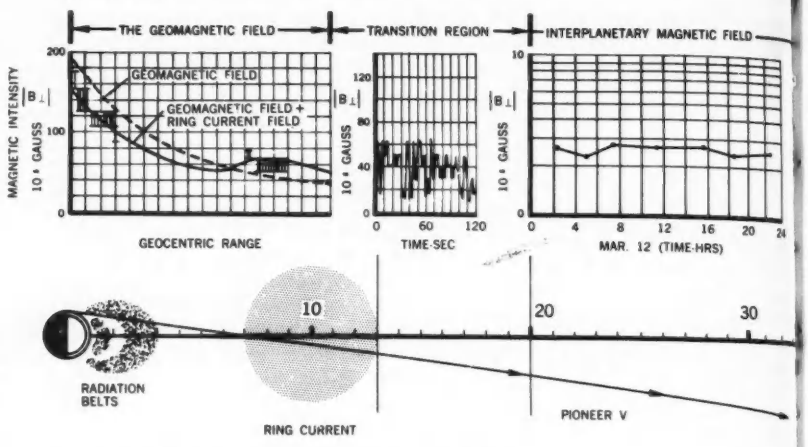
2. The interface of the geomagnetic and interplanetary field is now found to lie, during magnetically quiet conditions at a distance close to 14 Earth-radii—that is, twice as far off as the classical assumption which is 6 to 8 Earth-radii. This is immediately beyond the ring-current region.

3. The interplanetary field. During magnetically quiet day conditions, *Pioneer V*'s observations give solid evidence that there is a large-scale steady magnetic field in interplanetary space. This had been hypothesised by some workers. What has not been generally expected is the direction in which the field is now shown to lie. It makes a large angle with the plane of the ecliptic and, therefore, with the orbit of the Earth which is very nearly aligned with the plane of the ecliptic. How can this be? One suggestion possible at this stage is that there is a galactic magnetic field permeating the entire solar system. There are serious objections to this but they are not so great as the objection to rejecting experimental evidence for the sake of one or other of the previously held theoretical models of the magnetic field in space.

Under magnetic storm conditions there proves to be a direct correlation between events in space (of the order of 3 million km. from the Earth) and what occurs at the Earth's surface. Magnetic storms in interplanetary space directly produce magnetic storms on the Earth. There is no evidence that the ring-current flows during storm times; this result is derived by correlation with data from *Explorer VI*. This finding seems conclusively to dispose of the theory of incoming plasma producing a ring-current which in turn produces magnetic storm conditions on the Earth. There now proves to be direct electromagnetic interaction. Surface measurements of the field reflect in detail the magnetic conditions recorded far out in space.

Commenting on all this, Dr C. P. Sonett who is in charge of space physics research at STL, characterised a magnetometer flight in space as in effect a plasma diagnostic tool: "it it not clear what percentage of the energy of the universe is contained in magnetic fields, but there may be a significant portion of the total energy content stored in this manner. A number of astrophysical processes, perhaps most of them, are connected with the behaviour

Extra-terrestrial and Interplanetary Magnetic Field (*Pioneer V*).



Characteristics of the extra-terrestrial and interplanetary magnetic field as a function of distance from the Earth. (*Pioneer V*).

of magnetic fields." With the diagnostic tool aboard *Pioneer V* something of this picture is already becoming clear.

These are the results of the **radiation measurements** made by the University of Chicago group:

1. The sudden drop in the intensity of cosmic rays coming from the galaxy that occurs at the time of a solar flare and is known as a Forbush decrease is now conclusively shown not to be due to any mechanism associated with the Earth, but is a phenomenon of solar origin. An outstanding solar flare on March 30 produced a burst of plasma that reached the vicinity of the Earth and *Pioneer V* at about 0800 hours UT the following morning. *Pioneer V* was then travelling at 5 million km. from the Earth on the Sunward side. Instruments at the Earth's surface and those on *Pioneer V* both registered a sharp decrease in the cosmic rays; the loss was about 28% of all the incoming galactic cosmic rays at this time. As *Pioneer V* was then well beyond influence of the Earth's system the mechanism that produced this sudden drop must derive from the Sun. "It tells us that we are here dealing directly with a plasma ejection from the Sun. We do not know the details, but we know that there was a vast and extensive distorted magnetic field system in the vicinity of the Earth and *Pioneer V* on this occasion."

2. Conclusive evidence was obtained on the occasion of an unusual solar flare on April 1, that the Sun sometimes accelerates protons in its neighbourhood to cosmic ray energies and that these impinge directly upon the Earth without being held up in the Earth's magnetic field. Within 20 minutes of the onset of the flare a heavy increase in the proton flux was observed on *Pioneer V* and, simultaneously an almost total ionisation of the atmosphere over the Poles which persisted for many hours and must be attributed to the same cause—the arrival of solar protons travelling on a direct path from the Sun. The extremely short time taken for the journey shows these protons had been accelerated to cosmic ray energies, that is, were travelling at close to the speed of light.

3. The same flare provided evidence that solar electrons also are similarly accelerated at such times. Electron fluxes of the order of hundreds of times the cosmic ray flux were observed as *bremsstrahlung* in the *Pioneer V* detectors at this time and on similar occasions. *Bremsstrahlung* is the direct effect of the collision of high-speed electrons with the vehicle's skin and instrument casing. Gamma rays may have been present also.

All this helps to clarify the picture of what takes place when a magnetic storm is apparent on the Earth.

The results on radiation derived by the University of Minnesota group using a different instrumental system sensitive to different energy ranges are in good agreement with the Chicago findings, The Minnesota apparatus detected four different types of radiation—the Van Allen radiation in inner and outer zones, the galactic cosmic rays, solar produced low-energy cosmic rays (as described already) and solar produced x-rays. It is found that most Class 2 solar flares or greater produce the low-energy solar cosmic radiation and this of sufficient intensity

and penetrative power to be a serious biological hazard.

Continental Drift Theory Supported

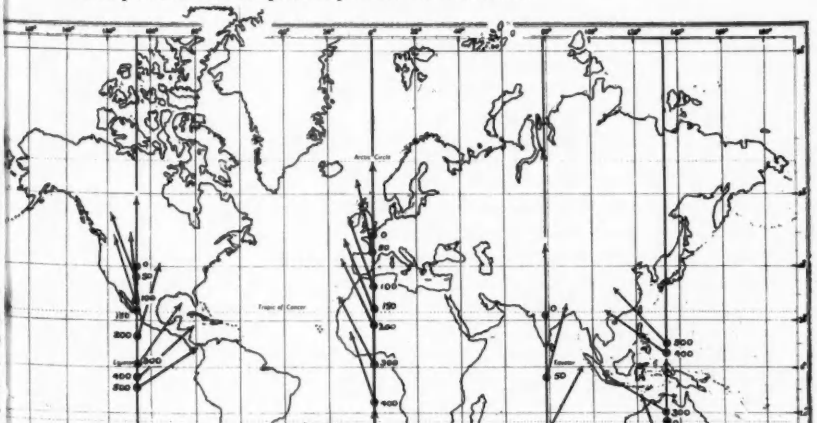
In a report on the total volume of evidence accumulated on the direction of magnetism of rocks from all over the world, Prof. P. M. S. Blackett, F.R.S., at a Royal Society meeting in May, came out strongly in favour of the theory that the continents of the world have drifted (and perhaps are still drifting) from their original location. This "continental drift" theory which was originally put forward early this century by geologists and has been the centre of bitter controversy ever since, suggests that all the land masses of the northern hemisphere were once contiguous—a single huge continent—and that this has, over ages measured in hundreds of millions of years, split apart and the individual pieces that we call the continents then gradually slid to their present positions.

The directions of magnetisation of rocks formed during the last ten or twenty million years are found, on the average, to correspond to the field of an axial dipole. On the other hand, the directions of magnetisation of more ancient rocks, those laid down one hundred or more million years ago, deviate markedly from those of an axial dipole; sometimes by as much as 90°. This analysis of all available rock magnetism evidence is now shown to give strong support to the hypothesis that in the distant past the continents were in quite different positions relative to each other and to the Poles than they are today. For instance, the direction of magnetisation of the oldest measured rocks in England point to its once having held a position roughly corresponding to that of the Sahara today. This would be one way of accounting for how coal seams, the indisputable evidence of a prehistorical tropical climate, occur at British latitudes. The magnetism of the rocks of India suggest that it was once part of the Southern Hemisphere close to the Antarctic Circle. Europe and North America appear to have moved northwards during the past 250 million years and to have rotated.

Prof. Blackett and his colleagues have also been considering the evidence available from palaeo-climatology and the findings so far agree rather well with the rock magnetism data and the continental drift theory. There is a belt of salt deposits lying across central Europe for instance, these are the normal results of a long continued semi-desert environment. Taken in conjunction with the distribution of fossil coral in Europe—and coral only flourishes luxuriantly in tropical waters—we have a picture of a primeval Europe that lay far to the South and considerably slewed round from its present position.

The report concludes that the rock magnetism data can be explained in one of two ways. Either the continents have drifted, or the Earth's ancient magnetic field was very different from that of an axial dipole. There are several reasons against the later hypothesis, so the weight of evidence is in favour of the drift of the continents.

This illustrates the position in the remote past of North America, Europe, India, and Australia, as derived from the rock magnetism data. The drift is plotted in terms of Denver for North America, Paris for Europe, Nagpur for India, and Alice Springs for Australia. Numbers indicate past time in millions of years. The zero point is then the present position of these cities.



Experiments for *Scout II*

Three British experiments are planned for *Scout II*. This is the second satellite out of three envisaged in the joint Anglo-American space programme and is scheduled for launching six to nine months after *Scout I* (expected launching date autumn, 1961).

It is not clear why there has been the long delay in announcing the contents of this satellite. The planning schedule was originally to be three months behind *Scout I* (announced early in February). A contributory factor has been the clash in requirements between the radio astronomy experiment and the ozone experiment (see these notes, March, 1960). A compromise position has now been arrived at which provides for a spin rate of 20 r.p.m. This should not entangle the long tape-like aerials of the radio experiment when they first uncoil upon vehicle injection into orbit and will be better than no spin at all for the meteorologists who wish to scan a spectrum.

The experiment instrumented by the Meteorological Office is directed to measuring the variations in the density of the ozone layer in the atmosphere, this lies between 20 and 70 km. up. Work by British scientists in recent years has shown that the ozone provides a valuable tracer of the atmospheric circulation at altitudes difficult to study otherwise. There is even some correlation apparent between weather changes and ozone variation so that the ozone distribution may prove useful for forecasting. The *Scout II* experiment will scan the ozone spectrum by looking through the layer at the Sun at sunrise and sunset for one minute each. This gives a total of two minutes observing time per orbit. A rapid rate of spin, say 140 r.p.m., would have enabled the satellite itself to do the scanning past a number of windows each with a different filter. A slow spin rate, however, involves either the use of moving parts to change the filters—not a desirable solution for a fully automatic operation—or a very curiously shaped "endless prism" to break up the light. The prism for this work is now under development and represents

one of the most complex instrument design problems that have yet faced space researchers.

The radio astronomy experiment is to be carried out by the Mullard Radio Astronomy Observatory, Cambridge, and is designed to record the very long radio waves that cannot penetrate the ionosphere and so cannot be observed at the Earth's surface. Nothing is consequently known about the characteristics of this part of radio spectrum below 38 Mc/s. On *Scout II*, radio waves of 1 Mc/s frequency will be studied and the aerials therefore have to be 100 ft. long.

Dr R. C. Jennison of Manchester University radio astronomy group proposes to use a sheet of thin aluminium foil to be renewed automatically every 24 hrs, to detect micro-meteorite impacts. The foil will be punctured by the incoming material and as the satellite rotates the Sun's light should shine through each hole and activate a photo-sensitive strip. The electric pulses produced by the photo-cell will give both the number and size of each impinging micro-meteorite.

SPACE CALENDAR

END OF APRIL

Symposium on space research in Canberra, attended by Sir Harrie Massey, chairman of the British space research committee.

APRIL

28 Announcement that an 85-ft. radio paraboloid will soon be ready at the Woomera rocket range for tracking space probes. It is 120 ft. high and located in a hollow to avoid outside radio interference.

MAY

2 The Minister of Aviation, Mr Duncan Sandys, reveals in the House of Commons that during discussions with the French and German governments on the possible use of *Blue Streak* by Britain as a satellite launcher these governments expressed an interest in a co-operative programme.

8 At approximately 8 million miles distance from the Earth the 150-watt transmitter in *Pioneer V* switched on by radio command from Jodrell Bank. A good clear transmission on the new instrument was received lasting about 1½ minutes. In order to effect this, two tube-heating sequences had to be switched in by remote command considerably in advance of the actual first transmission.

12 Attempts to launch a 100-ft. inflatable balloon with radio reflecting properties into a satellite orbit from Cape Canaveral failed. This second satellite balloon failure—two less ambitious trials have been successful—was due to a misfunction in the second stage of the rocket launcher.

15 Russians placed a 4½-ton spaceship into orbit as a propaganda gesture on the eve of the (abortive) Summit conference. Said to be a full-scale manned spaceflight systems trial, complete with a dummy man aboard. Separation of the capsule to be attempted but not recovery of this. Weights: cabin—2½ tons; cabin instrumentation—1½ tons. Orbit: nearly circular, varying between 194 and 230 miles altitude, and passing over Paris, New York, London, San Francisco, Melbourne, and Ottawa possibly as a daylight object on its first day of existence. This is the second anniversary of the launching of *Sputnik III*, the last *sputnik* launched by the Soviet Union. Tracking signal broadcast on 19·995 Mc/s. Period: 91 minutes.

19 French successfully launched a 4-stage rocket (supposedly a re-entry vehicle) to 93 miles from the naval experimental station on the Ile de Levant off Toulon. The fourth stage, fired during the descent, accelerated the vehicle to 5000 m.p.h. by the time it was within 15 miles of the surface.

20 Capsule of the Soviet "spaceship" launched May 15 separated by radio command from the ground with a view to descent. Misfunction of the system caused both "ship" and detached capsule to go into higher orbits instead of lower. Braking rocket fired at wrong angle so acted as accelerating device. New orbits for both objects roughly between 191 and 249 miles altitude, with 94-minute period. Up to this environmental system said to be "proved".

20 *Atlas* successfully completed a 9000-mile trajectory, a third of distance round the world thus beating the January Soviet long-distance missile record of 7760 miles. Achieved over the Atlantic from Cape Canaveral by directing missile briefly into a satellite orbit. Dropped into restricted target area planned but no recovery attempted.

24 Two-and-a-half-ton American *Midas* satellite successfully launched from Cape Canaveral into a 300-mile-high, near-equatorial orbit. Of this all-up weight the instrument package contributes 3600 lb. *Midas* stands for Missile Defence Alarm System, and *Midas II* is the first test of a system ultimately expected to involve a dozen or more satellites simultaneously in orbit, and designed to provide earlier warning of enemy missile firings than the DEW-line radar system. The radar detection system gives the U.S. fifteen minutes' grace to take retaliatory action; *Midas* should give thirty minutes' warning since it could detect a firing within seconds of the missile leaving the ground. Detection is by means of super-cooled high-sensitivity infra-red sensors able to observe the hot gases emitted by the rocket engine during boost at extreme range. This information is radioed to ground control centres to alert the defence system. Test flares were to be fired during the days following the launch to test the sensors' efficiency. Test orbit attained was designed not to pass over Soviet territory.

Sixth successful test of *Black Knight* rocket at Woomera. A high-velocity re-entry was aimed for rather than a great altitude. Firing of the second stage was delayed until the rocket was descending, thus boosting the speed of the nose-cone at re-entry to 10,000 m.p.h. The glow from the nose-cone during its descent through the atmosphere illuminated the night sky above the range.

26 *Midas II*'s radio failed after two days in orbit.

27 *Aerobee-Hi* instrumented by the U.S. Naval Research Laboratory with eight ultra-violet "telescopes" for observing the ultra-violet spectrum from stars made a successful flight to 137 miles high.

28 Mr H. Watkinson, British Minister for Defence, left for the U.S. to negotiate the purchase of large American solid-fuel defence missiles as air-to-ground and other defence weapons for Britain. *Skybolt*, *Minuteman*, and the submarine-launched *Polaris* are all likely candidates.

THE BOOKSHELF

Principles of Optics

By Max Born and Emil Wolf (*London, Pergamon Press, 1959, xxvi+803 pp., £6*)

This is undoubtedly the most important text-book on optics to be published anywhere during the past thirty years. At last we have a worthy and up-to-date successor to the classical Gehrcke's "Handbuch der Physikalischen Optik". It is a successor, yet indeed a better book. This treatise is a considerable expansion, in English of Born's very well known "Optik", which appeared first in 1933, but it is no mere translation; it is a new book and much more comprehensive. The preface tells us that this book omits numerous branches of optics, such as the optics of moving media; the theory of optical, x-ray, and gamma-ray spectra; the optics of the eye; and all of classical molecular optics. It continues with a modest understatement that the discussion is restricted to the optical phenomena which may be treated in terms of Maxwell's phenomenological theory. Yet indeed the content is vast and formidable, thorough, and complete.

The first two chapters (107 pages) are devoted to an extensive treatment of electromagnetic field theory and of polarisation. Chapters three, four, and five (126 pages) cover geometrical optics, that is optical imaging and the theory of aberrations. This is treated from a practical as well as a theoretical standpoint. The subject of geometrical optics is shown to follow from Maxwell's wave theory as a limiting case of short wavelengths. The more difficult mathematical treatments are put into the appendices.

P. A. Wayman's contribution is a quite brief account of image-forming instruments such as the camera, telescope, and microscope. Then follows "Interference and Interferometers" (contributed by W. L. Wilcock). This formidable chapter of 113 pages is in itself a good and complete monograph on interferometry, especially good on the experimental side of the subject. It is thorough, compact, well illustrated and right up to date.

Chapters eight and nine (120 pages) deal with that nightmare for the undergraduate student, diffraction theory. It contains everything the student requires, and also a good deal more than that. Kirchhoff's theory, gratings, the microscope, phase contrast, Fresnel diffraction, Gabor's wavefront reconstruction, diffraction theory of aberrations, and so forth. These are some of the aspects treated exhaustively. It is certainly tough going for the student, and contains much more than is needed in the honours degree. It is especially here where the specialist student in optics or in technical optics will find tremendous help in one of the most difficult branches of his chosen subject. The optical research worker will also be especially interested in chapter ten which treats of partially coherent light, for this is a branch of optics which is at the moment exciting a good deal of active interest. This chapter, and the following (written by P. C. Clemmow) takes up 100 pages. This makes difficult reading but together they make up a most valuable reference section. There follows a brief chapter (by Prof. Bhatia) on "Diffraction of Light by Ultra-Sonic Waves". Finally there are two important chapters, "Optics of Metals" and "Optics of Crystals." These are based essentially upon the corresponding chapters in Born's "Optik" but have been revised respectively by Prof. A. M. Taylor and A. R. Stokes.

The mathematical appendices occupy no less than fifty-eight pages and there is a comprehensive index. The encyclopaedic character of this treatise makes it naturally expensive, yet it is so important a text that not only is it essential in every library and laboratory, the student also, if he can afford it, should certainly secure his own copy. The production is excellent and the illustrations numerous and admirable. We welcome this book; it will remain a standard text on physical optics for years to come. S. TOLANSKY

Early India and Pakistan

By Sir Mortimer Wheeler (*London, Thames & Hudson, 1959, 241 pp., 25s.*)

The Pre-Historic Background of Indian Culture

By D. H. Gordon (*Bombay, N. M. Tripathi Ltd, 1958, xxii Pl.+199 pp., 45s.*)

There has long been a need for publications on Indian archaeology for the non-specialist reader. Both the books reviewed here are intended as such: "Early India and Pakistan" is aimed primarily for English readers and belongs to the general series "Ancient Peoples and Places".

Perhaps the most interesting idea that emerges from Wheeler's consideration of the remote past is the suggested link between finds in India and those in neighbouring regions. In speaking of the Indian palaeolithic for example he refers to "the unitary aspect of the cultures fringing the Indian ocean", in this case East Africa, Arabia, and the west coast of India. Intercommunication within this area was known during the historical period (from the 1st century B.C. onwards), and is documented in literary evidence. The fact of its having been known earlier would be of great assistance not only to the study of Indian archaeology but also to the reconstruction of the East African past.

The most outstanding event of Indian prehistory is the emergence and development of the Indus Valley Civilisation, or the Harappa Culture as it is sometimes called (*c.* 3000–1500 B.C.). The origin of the people who built this civilisation appears not to have been finally settled. Gordon maintains that the Indus Valley Civilisation was a colony of the people of Sumer and Elam, and postulates 2600 B.C. as the date of the arrival of the "founding fathers". This view is not acceptable to Wheeler who argues that the civilisation was indigenous, but that it had contact with those of Mesopotamia; though not a colony, it nevertheless had some similar features and borrowed ideas from the latter. This problem can be settled only by more extensive excavations both at the important centres of this culture and at fresh sites included within the scope of the culture. A comparison of evidence from pre-Harappa levels may provide the answer.

The cause of the decline of the Indus Valley Civilisation has also produced a number of hypotheses. Wheeler suggests that the deterioration in the culture was accelerated by the frequent and disastrous flooding of the Indus river, which repeatedly damaged the city of Mohenjo-daro, one of the two nuclei of the culture. Bricks for rebuilding the city were fired in kilns which were heated by wood. This led to the denudation of the forests which in turn caused a change in the climatic environment and contributed to the decline of the culture. Gordon suggests technical stagnation though he does not explain why. The Aryan invasion from the north-west dealt the final blow. It is clear from the material available that there was a technical stagnation towards the end of the Harappa Culture. The reason may be sought in the social structure. Forced labour, and what Gordon describes as slavery, increased in the latter

period. The increased leisure available to some members of society may not have been utilised in the improvement of techniques, but rather in the excessive enjoyment of what already existed; a situation not uncommon to the declining years of many civilisations.

Gordon's consideration of rock paintings and engravings provides an introduction to a subject which has been generally neglected by Indian archaeologists. These paintings are not only largely secular, but they date from the prehistoric period until well into the historic period (the later centuries, A.D.).

Gordon's work sets out to explore only the prehistoric background. Wheeler, though calling his book "Early India and Pakistan", emphasises only the evidence from archaeological remains. The relating of this material to literary evidence (even briefly) would have improved the latter study. For instance, the extensive use of iron by the Aryans in northern India was a characteristic feature; a connexion between the objects found and the reference to iron in Vedic sources may provide valuable results. The study of India's antiquity has admittedly suffered from a bias on the side of literary evidence. An insistence on archaeological data is therefore essential. But the neglect of literary evidence might lead to an equally sad bias on the side of artifacts alone. R. THAPAR

DSIR, Report of the National Chemical Laboratory 1958

(H.M.S.O., iv+79 pp., 5s. 6d.)

This is the first report by the Director since the renaming of the Laboratory. Its functions have been defined as first carrying out fundamental chemical research inappropriate for universities and other research organisations, second, basic chemical researches of a wide general application to many industries; and third, chemical researches of an objective nature for industry on repayment. Rapid progress is reported with the extension of the radio-chemical building, designed mainly for large-scale work on the extraction of metals from ores by hydrometallurgical processes and the completion of a new laboratory for the preparation of pure elements in dust-free conditions. Among studies in hand, particular attention is drawn to work on the extraction of metals especially for the Atomic Energy Authority, on the preparation and properties of pure elements and compounds, on the corrosion of metals, on the Development and application of new materials, especially for the National Research Development Corporation, on analytical research and services, and work in the field of Microbiology. It will be noted that the Laboratory is responsible for three important classes of standard materials which are available on request for research purposes—pure metals, organic compounds, cultures of industrial bacteria —the latter collection, established as a result of recommendations of the British Commonwealth Scientific Official Conference of 1946, is unique in character. An account is also given of the Laboratory's advisory services and of the principal types of advice tendered in the fields of immersed, underground and microbiological, and atmospheric corrosion, and purification techniques.

The report specifically relates the Laboratory's activities to the industrial, social, and economic setting concerned. Thus, the annual cost of corrosion in the United Kingdom is estimated at £600 million, and it is in this perspective that the Laboratory's extensive researches into this subject should be viewed. Similarly, there is the fact of the United Kingdom's virtual dependence on imports for its sulphur supplies. Prospects for indigenous production are being explored, particularly the possibilities of microbiological sulphate reduction. In this connexion, a relevant survey showed that sewage sludge

B J P S

The British Journal for the Philosophy of Science

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Science Survey One

edited by
A. W. Haslett and John St. John

Foreword by
Sir George Thomson, F.R.S.
President of the British Association

This survey, produced with the co-operation of the British Association for the Advancement of Science, is a long-required authoritative record, written for the general reader. The first issue includes twenty-six chapters on recent developments and advances in the scientific world, set out under seven major headings.

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The Earth
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A. Manning, D.Phil., on *Evolution of Courtship Behaviour*

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was the only suitable reducing material cheaply available in sufficient quantities, and its potentialities are receiving further study. Clearly, the Laboratory has a formidable range of scientific achievements to its credit and moreover, it is undeniable that its effort is being deployed in the light of the relative importance of our contemporary problems.

The Emergence of the German Dye Industry

By John Joseph Beer (*Urbana, The University of Illinois Press, 1959, vii+168 pp., $3.50*)

The manufacture of coal-tar dyestuffs began in Germany on a very small scale during the 1860s. Twenty years later it had become a flourishing industry, and by 1900 a handful of large firms dominated the world production of dyestuffs. Among the chief factors contributing to this remarkable industrial development were the extensive research laboratories staffed by hundreds of scientists, and a thrusting and efficient commercial organisation.

Such, in outline, is the theme of this well written, informative and concise account of an extremely significant chapter in modern industrial history. The available information is considerable and, given the limitations imposed by a slim book, the author has handled his subject with discrimination and rightly devoted particular attention to the evolution of one large firm, Farbenfabriken Bayer, which mirrors that of the industry as a whole.

One disadvantage of this approach to a controversial subject is that, for reasons of space, the broad background can only be discussed in general terms. However, the opening chapters, though brief, contain a perfectly adequate summary of the rise and decline of the dyestuffs industry in Britain and France and the neglect of scientific education in both countries. Unfortunately the concluding chapters, which take the story from the early years of the 20th century to about 1939, do not come up to the high standard of the rest of the book. In particular the far-reaching structural changes in the German dyestuffs industry caused by major alterations in the pattern of production require fuller treatment.

Apart from this criticism, the book is remarkably free from minor errors, though the account of the lignite (not coal) mines on page 139 is misleading and the names of several eminent chemists have been misspelt; the absence of Kekulé's name from the roster of organic chemists is surely unjustified. Nevertheless the monograph serves as an admirable introduction to the German dyestuffs industry and can be highly recommended to chemists no less than to students of economic history. It is to be hoped that this valuable contribution to the Illinois Studies in the Social Sciences will encourage the author to write a full-length book.

L. F. HABER

Grundlagen der Chemie für Ingenieure

(*Berlin, Geissler, Schiele & Schön, 1959, 14th edition, 86 illustrations, 230 experimental instructions, 285 pp., appr. DM32*)

This is easily the best German course in chemistry for students of technology, and I review it here as a teacher of technical and scientific German, with long years' experience of German texts for both chemists and engineering students. In all such courses, the number of which are now in continuous ascent, such a book will be of great value to students and instructors alike. The author, well known in Germany by his earlier work, "Wärmetheorie, Wärmetechnik, Wärmewirtschaft", has here presented in short chapters and with very clear headings and sub-divisions, the whole matter of chemistry such as is of immediate and practical use to the metallurgist, the heat or chemical engineer, and in many ways for the biochemist in industry. The book makes a timely appearance in Britain, where just now many colleges and university faculties intensify their reading courses in technical publications in foreign languages. A book such as this will find many eager learners and readers, where a duller book may fail. J. HORNE

Elements of Physical Metallurgy

By Albert G. Guy, Second edition (*Addison-Wesley Publications Inc., 1959, 528 pp., $9.50*)

The teaching of physical metallurgy has never been easy, for a balance has to be struck between the different approaches of the physicist, the metallurgist and the engineer. In recent years there has been a tendency to look upon physical metallurgy as just one branch of the more fashionable topic, solid state physics, and this again has not made life easier for the teacher of metallurgy, as there has been a plethora of text-books on solid state physics with badly written chapters on physical metallurgy coming into the hands of his students.

Prof. Guy has not been too heavily swayed by the fashionable views of the solid state physicist and has written an excellent text-book on physical metallurgy in the classical manner. This book, which should whet the appetites of first year students of metallurgy, is greatly improved from the first edition; new chapters on dislocations and on phases in metal systems have been added whilst throughout there are some excellent micrographs and line diagrams. A well selected group of references is given at the end of each chapter and these form a useful guide to further reading for the untutored student. There are also lists of problems on each chapter which, apart from testing the comprehension of the subject, indicate the topics examiners consider important.

An attempt to produce an elementary but comprehensive account of physical metallurgy must inevitably lead to a long book, which is consequently expensive. However, as the present volume is probably the best of its type now available it provides a worthwhile investment for the student. J. NUTTING

A Forgotten Kingdom

By Sir Leonard Woolley (*London, Max Parrish & Co. Ltd, xiv+178 pp., 30s.*)

Sir Leonard gives here a popular account of his 1936–49 excavations at al Mina and Atchana, two sites in the Turkish Hatay near Antioch. Al Mina is identified as the ancient port of Posideium, and Atchana as Alalakh, by numerous documents found during the excavations. One of these documents is a detailed history of Alalakh, which contains references to Sumer, Babylon, Egypt, and the Hittite empire, and throws new light on economic aspects of the Athenian empire. In view of this, Sir Leonard argues that excavations of insignificant sites can contribute information as important to our understanding of history through reconstruction of the past as that obtained from the excavation of the great ancient cities.

Man's Emerging Mind

By N. J. Berrill (*London, Dennis Dobson, 1958, 308 pp., 21s.*)

Dr Berrill, a biologist, speculates in a conversational tone, on the nature of the evolution of the human mind. He argues that modern man is probably descended from a creature similar to the australopiths, or man-apes, whose remains were recently discovered in Kenya. He constructs a hypothetical mind on the basis of such evidence as fossil skulls and the type of brains they probably contained, and the observed behaviour of monkeys and apes. He then suggests the manner in which environment and natural selection brought about changes which produced the mind of modern man. For the layman the book provides a very readable account of the prehistory of man.

The Earth Beneath the Sea

By Francis P. Shepard (*Johns Hopkins University Press, 1960, xii+275 pp., 30s.*)

Prof. Shepard has written a readable and interesting book of 275 pages which includes an index and 113 illustrations. In addition, he has entered a geological time scale which is always useful in a discussion of the Earth or Earth processes. He has listed ten publications in a briefly annotated bibliography for suggested additional reading.

The printers have done an excellent job with the book. All figures and photographs are clearly reproduced, and I cannot find any typographical errors at all. The book is well bound and is printed on quality paper; and as books go these days, it is reasonably priced.

There are only one or two mildly critical remarks I can find to make. For instance, Dr Shepard might have noted in Fig. 10, page 31, that the ripple marks lying at 4500 ft. in depth on Sylvania Seamount are composed of the tiny shells of a widespread form of foraminifera called globigerina. These shells are very light and easily moved about, which in some sense gives a qualitative clue to the strength of the currents causing the ripple marks. It might also be explained in Fig. 99, page 222 that Halimeda are algae. I cannot find Fig. 99 referred to in the text, but perhaps such reference is not particularly necessary in a popular treatment. Small criticisms such as these detract in no way from the value and readability of this fine book.

For the first time in a book on the sea for the general reader, we find included unique illustrations which have not appeared elsewhere in the popular literature. An example is the map of the sea floor in Eniwetok atoll. This highly detailed chart shows the complicated nature of a coral atoll, and is printed here for the first time.

Dr Shepard's discussion of tsunamis, particularly the one striking Hawaii in 1946 is outstanding. He and Mrs Shepard were eye-witnesses to the disaster and narrowly avoided becoming a statistic as a result. The astounding wave in Lituya Bay in July of 1958 along the south coast of Alaska which reached a height of 1700 ft. up the mountain is well described and is a very much up-to-date piece of information on catastrophic waves at sea.

Dr Shepard has done admirably well in tying together the processes that work in the sea with those that work on our beaches and the continents. In our attempts to understand the sea, we sometimes confuse processes at work in continental regions with those quite different processes going on in the ocean. In this book such processes have been mentioned only where they belong.

The book is well arranged in twelve chapters covering the sea floor, coral reefs, continental shelves, deep-sea canyons, and various other interesting aspects of marine geology. Now that considerable emphasis is being placed on the oceans in United States and in several other countries, the book is timely in that it helps bring to the public some of the need for this emphasis and the magnitude of the problem facing those who would understand the oceans.

G. LILL

Culture in Private and Public Life

By F. R. Cowell (*London, Thames & Hudson, 1959, x+357 pp., 30s.*)

It is right and proper that scientists should sometimes turn aside from the pursuit of science to consider culture. The shortsighted view is too much with us, that science is merely a means to multiply *things*, that the purpose of the new university departments and technical colleges and schools is solely to make the country rich in economic goods, in motor cars, nylon stockings, nuclear power stations, and tranquillisers. In 1830, the French mathematician Jacobi wrote: "M. Fourier believes that the chief aim of mathematics is its public usefulness and its explanation of natural phenomena, but a philosopher like him ought to have known that the sole aim of science is to do honour to the human spirit." And George Sarton, the great historian of science who died in 1956, concluded that "the history of science is the only history which can illustrate the progress of mankind. In fact, progress has no definite and unquestionable meaning in other fields than in the field of science."

Mr F. R. Cowell defines culture as that which gives meaning to life and he groups the things which give life its value into those which contribute to truth, to beauty and to goodness. In pursuing this definition with considerable erudition through 357 pages he travels a remarkably long way. Truth encompasses knowledge and life may be enriched even by so minor a cultural activity as the collection of match-box tops. Goodness, too, leads Mr Cowell to condemn what he sees as our modern badnesses, among them communism, death duties, and pornography.

This is a long and serious book and it contains the fruit of considerable scholarship. If here and there the author's pet prejudices run away with him, we are compensated by shrewd and interesting thoughts. As scientists, who within the last two generations have turned understanding of the physical world upside down, we do well to be reminded, as Mr Cowell reminds us, that the crisis of our times is a cultural crisis and that it is to a large measure we who have shown the inadequacy of accepted ideas in natural science who have weakened the traditional lore of our cultural background. M. PYKE

Dynamics of Behaviour

By R. S. Woodworth (*London, Methuen & Co, Ltd, 1959, 403 pp., 36s.*)

Prof. Woodworth argues that there is a "dynamic" relationship between motivation, on the one hand, and learning, perception, and thinking, on the other, as these processes are themselves motivated. In turn, motivation depends on how a situation is perceived and understood, and on habits and ways of meeting a situation which have been previously learned.

"Dynamics of Behaviour" offers fundamentally the same point of view as that put forward by the author in his book, "Dynamic Psychology", published in 1918, but there are differences of emphasis and the book has been brought up to date. The theories of motivation of Freud, Hull, and other behaviourists are analysed, and such subjects as the motivation of group behaviour, the "achievement" of motives, different types of learning, and problem solving are discussed. Prof. Woodworth offers this book as a supplement to his well known "Experimental Psychology".

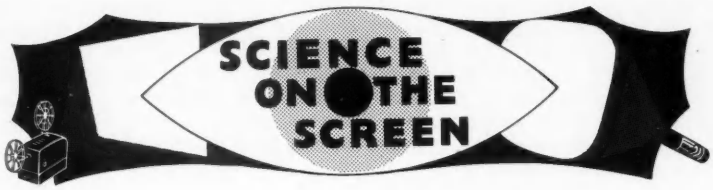
Constitutional Diagrams of Uranium and Thorium Alloys

By Frank A. Rough and Arthur A. Bauer (*London, Addison-Wesley Publishing Co., Inc., 1959, vi+153 pp., $5.00*)

This volume supersedes the Battelle Memorial Institute publication BMI-1000, entitled "Compilation of U.S. and U.K. Uranium and Thorium Constitution Diagrams". It presents in a revised and more permanent form the large amount of information contained in this hitherto standard reference source.

Short sections on the melting and phase relations of uranium and thorium are succeeded in each case by data for binary and ternary systems containing these metals, listed in alphabetical order of the additional components. Phase diagrams are reproduced for many systems, and care has been taken to include all possible data for systems for which phase diagrams are not yet available.

Such an important and accessible collection of facts will be of general value for reference, although rapid advances may make revision and extension necessary after a quite short period. The material is well presented and fully referenced, and the phase diagrams are clearly reproduced. A. J. E. WELCH



The Seashore

16 mm. Sound. Colour. Running time 20 minutes. Produced by Plymouth Films Ltd for EFVA. Educational Advisers L. E. Higson, B.A., B.SC.; Gwynne Vevers, M.B.E., M.A., D.Phil.

Isotopes

16 mm. Sound. Colour. Running time 15 minutes. Produced by Greenpark Productions Ltd for UKAEA, Dunlop Rubber Co. Ltd, Griffin & George Ltd, Clarke & Smith Manufacturing Co. Ltd, and EFVA. Educational Adviser: G. Winchcombe, B.SC.

(*Both these films are available for hire from EFVA Film Library, 33 Queen Anne Street, London, W.1.*)

With the impact of television making itself felt in all forms of journalism and film making, it is useful to reflect that it is in the field of education that film and television meet on an equal footing. The Educational Foundation for Visual Aids showed recently its two latest productions which well illustrate this point.

The first, *The Seashore*, was produced in direct response to requests received from teachers for an ecology film showing the relationships between the plant and animal life found in the various zones of the seashore. It is a very carefully thought out film, having as advisers Miss L. Higson and Dr G. Vevers, though in execution leaving something to be desired. The subject depends upon colour and clarity, and these qualities are not at their best. It may well be that a low budget, library shots, and indifferent processing have taken their toll. The film, however, is quite clear on essential details: the close-ups of fish and animal life, and the cinemicrography of plankton are admirable.

Isotopes, the other film, brings the total in the now well known EFVA Advanced Science Series to twelve. This series is designed for science specialists in the Sixth Forms of Grammar Schools and for students at a similar level in the Technical Colleges, though, of course, in practice it has a very much wider application. The films normally give a round-up of material on the most recent developments and apparatus, such as *Principles of Chromatography*, *The Spectrograph*, and *Principles of the Transistor*. *Isotopes* gives information and experiments not readily available in schools. The series from the beginning was conceived as a joint venture with industry and would not have been brought to fruition were it not for this support. In the case of *Isotopes* a new departure can be seen with the financial support coming from four different companies in contrast to the usual single company interest.

After an opening dealing with the Gaseous Separation Plant at Capenhurst the film moves rapidly through a definitive sequence and historical background. The second half of the film discusses radioisotopes and takes four typical uses as examples: in thickness gauges, as tracers; as a source of gamma rays for gamma-radiography; and as a source of gamma rays in the treatment of cancer.

The production values of the Advanced Science Series have always been directed towards getting value for money. *Isotopes* is no exception. And for industry the series must surely be one of the most rewarding ways of assisting scientific film making

F. BAMPING

FILMS FOR POSTAL WEEK

Counterpoint

16 mm. and 35 mm. Sound. Black and white. Running time 18 minutes. Produced by Basic with COI, for General Post Office.

Machines to Move the Mail

16 mm. and 35 mm. Sound. Colour. Running time 17 minutes. Produced by Marcus Cooper with COI, for General Post Office.

Two new films made for the Postal Week (March 14–21) and for public use thereafter were introduced to the Press by the Postmaster-General at a previous Press show.

The first of the films, *Counterpoint*, told a personal story of how the Post Offices and their staffs fit into the framework of society. It was no exercise in sociological film-making, however, but rather put a case for improving mutual understanding between the public and the counter-clerk. The film got off to a bad start with the phoneyness of the actor's voice attempting to lend character to the role of the clerk. The *leitmotiv* music also became a bore, through its indiscriminate use. Only once did it add anything to the point of the film, where the visuals were cut to the music.

The protagonists for this natural (it can hardly be called realistic) school of film-making seem to have the ground cut from beneath them by their use of actors and atypical situations and surroundings. Hence the contrast between *Counterpoint* and the "honest-to-goodness" approach of the second film, *Machines to Move the Mail*. Here statements are backed up by fact and the film reveals the progress to date in developments in postal mechanisation, and glimpses of the future at the Dollis Hill Research Station.

Machines to Move the Mail was made with the help and co-operation of the Union of Post Office Workers. This shows their confidence in the Post Office, for the film in contrasting the machine operations with the existing manual operations draws the conclusion that mechanisation is something to be welcomed.

Both these films are now available on hire for showing to clubs, societies, and so forth, from the Central Film Library, Bromyard Avenue, London, W.3.

F. BAMPING

Three films from the United Kingdom Atomic Energy Authority

The Atomic Authority has a catalogue of about twenty-eight films. These show the construction and functioning of various atomic plants, including Calder Hall, Chapel Cross, and Dounreay. There are also films on Safety, Nuclear Power, The Principles of Nuclear Fission, and Radioactive Isotopes. Most of these films are available on free loan, but some must be borrowed from the Central Office of Information Film Library at a reasonable hire charge.

The Dounreay Fast Reactor

16 mm. and 35 mm. Sound. Black and white. Running time 38 minutes. Produced by Ace Film Productions for United Kingdom Atomic Energy Authority. (*Available on free loan from The Public Relations Branch, UKAEA, 11 Charles II Street, London, S.W.1, Risley, Warrington, Lancs., or Ace Distributors Ltd, 14 Broadwich Street, London, W.1.*)

This is a simple constructional record of the erection and assembly of the Fast

Breeder Reactor. It shows rather too slowly for any but the very specialised audience, every detail of fabrication and installation within the dome, of the coolant circuits, the reactor vessel and the core.

Details are filled in by simple diagram. The commentary by Frank Phillips is clear, but, as is the case of many films of this type, every word was as complex as it could be. It is surely possible to combine the correct technical words with simple everyday English?

One of the most complicated stainless steel vessels built in the United Kingdom, and probably in the world, was installed at Dounreay. The audience sat through every detail, mainly patiently, but in a small audience someone behind me was gently snoring; which is an indication that even the most technical film must be given tempo and impact.

At one point in the film there was complete silence. This was most stimulating. It is strange that most human beings need silence in order to stimulate their listening.

This was undoubtedly one of the most thorough and detailed constructional films your reviewer has seen. It shows with extreme care how this immense dome was filled with complex equipment specially designed and carefully fabricated. Every part was checked and cleaned. Every morsel of dust was removed by vacuum cleaners.

This film once more poses the problem of goal. What audience is it intended for? As a record, and a very valuable one, it is nearly perfect. One feels that, if a future fast breeder reactor is required, here is technical documentation on film which can be used with the other records to make construction easy. It will also have very great value for the staff who work at Dounreay. It will show them the things which they can no longer see, and may even help in practical maintenance.

On the other hand, it is rather too long for an audience of students, or others whose interest is less profound. An excellent film for loan could be made from the same material, but lasting half the time. It is once more a question of choosing your audience and making a film to suit them. This has been done most successfully, but it strictly limits the use of th[illegible]lm with other groups.

Operating a Calder Hall Type Reactor
Part 2 Refuelling

16 mm. and 35 mm. Sound. Colour. Running time 32 minutes. Produced by Ace Film Productions, for United Kingdom Atomic Energy Authority. (*Available on free loan from the Public Relations Branch, UKAEA, 11 Charles II Street, London, S.W.1, Risley, Warrington, Lancs., or Ace Distributors Ltd, 14 Broadwich Street, London, W.1.*)

This is the second of a series of three films produced, in the first case, for instructing nuclear power station operators. This part describes the discharge of used fuel and its replacement by new fuel elements, in Calder Hall Type Reactors.

Part 1 of the series which lasts ten minutes is called *Full Power* and shows the operation of Calder Hall Type Reactors producing electricity under normal conditions.

Part 3 *Starting Up* is not yet complete, but is in its final stages. It will describe how a Calder Hall Type Reactor is started up after a shut-down.

The colour is very good and is used intelligently during the diagram sequences. The treatment is relatively simple and clear. Each process is shown either by diagram, cut-away model, or actual live shots, whichever method seemed to be the best way of showing the process. The commentary is by one of the staff at Calder Hall—the Works Manager—and although there is the slightest echo of an Army Instructor in his method—the result is clear cut. Anyway the film is teaching a drill, and a drill which must be slavishly followed, so this simple method is fully justified.

The overall impact is clear and precise. The one difficulty for the layman, and possibly even for the newcomer to Calder Hall, is that many of the components look so alike that it is difficult to distinguish between them. For its avowed purpose it would obviously be combined with practical demonstrations and on the spot visits, so this problem could easily be overcome.

This film of its kind is very good indeed. Like all well-designed, functional, and down-to-earth tools, it has a certain intrinsic beauty, It cannot be described as an art film or a poetic documentary of course: but it is intellectually and visually satisfying. This is more than can be said of the large majority of instructional and industrial films.

Winfrith Pipe Line

16 mm. and 35 mm. Sound. Running time 42 minutes. Produced by Ace Film Productions for United Kingdom Atomic Energy Authority. (*Available on free loan from the Public Relations Branch, UKAEA, 11 Charles II Street, London, S.W.1., Risley, Warrington, Lancs, or Ace Distributors Ltd., 14 Broadwich Street, London, W.1.*)

This is a constructional film showing the principle and the practice of the disposal of the radioactive effluent from a nuclear power plant. The Winfrith installation is near Lulworth Cove, so it was decided to run a pipeline across country to the sea and have an outflow two miles out at the bottom of the sea.

There is a pipe within a pipe, in the inner one is the potentially dangerous waste and in the outer the harmless effluent. The operation was planned to give the least possible interference with farm-land and the beauty of the countryside. The method by which the pipes were welded and radiographed is clearly shown. Through the first part of the line, the effluent is pumped to a tank on a high point. From here until the discharge under the sea the flow is by gravity. The land part of the operation is clearly shown, factual, and quite interesting. If one has seen films on the pipelines laid by the great oil companies, there is no violent difference, except the very much greater care required.

When it comes to the beach then the film becomes absolutely fascinating. The underwater sequences are excellently photographed. A detailed survey of the reefs had to be made, then they had to be blown up so that the pipe could be placed on a smooth surface. This was shown in detail with clear diagrams to show the sea-bed and the blasting operations. It was a line and level job underwater. Some of the civil engineers used a fascinating gimmick. A powered underwater scooter —a sort of miniature human torpedo, which the frog-footed operator hung on to, while travelling fast along the pipeline.

The use of an army DUKW was shown, which is always interesting. The colour is good, and the comparison between the use of the standard diver in his heavy equipment and the skin divers in their light equipment is revealing.

This is an insight into the film medium. After the beginning, which is slow, factual and instructive; the second part, which really moves at the same speed gives an impression of a much faster tempo. For when there is romance and excitement film really comes into its own. Even though the submarine sequences are just as factual as the early parts of the film, they seem much more stimulating.

L. GOULD-MARKS

May Television

For long we have insisted and reiterated in these columns that the ideal science television broadcasts are those which bring to us, effectively in one broadcast, *one* distinguished scientist giving us an illustrated summary of some of his work.

We have long felt that such a broadcast, lasting thirty minutes, gives a much more intimate and genuine picture of current scientific researches than those wildly puffed-up over-elaborations, exhibiting giant machines or big organisations, each bigger, costlier, and more overpowering than ever before. It is therefore with pleasure and delight that we note now that each weekly broadcast in the BBC television series "Eye on Research", devoted ostensibly to the tercentenary of the Royal Society, is in fact concentrating precisely, as we have always hoped it would, on the work of one or perhaps two distinguished investigators. Week after week we are being enthralled and entranced by a scientist of distinction leading us to that exciting boundary between the known and the unknown. There are no trappings, no huge appliances, no gasps at a fantastic this or an enormous that, but essentially, each time, a quiet, serious investigator, by a few deft illustrations, opens up an exciting future.

On May 10 this series gave us *The Living Batteries*, which was an absorbing account by Dr H. W. Lissman, F.R.S., and Dr R. D. Keynes, F.R.S., of their separate, yet closely related, studies on the electrical phenomena generated by a number of fishes, long known but till now little understood. With nothing more elaborate than a few fish in tanks and some simple electrical detecting instruments, we were shown vividly how a multiplicity of single electrolytic cellular formations can produce from live animals startlingly high potentials of over 3500 volts. On the one side we saw the effects of the final high voltages, on the other the beautifully simple, yet very elegant, micro-electrode techniques which establish that each cell produces but $\frac{1}{8}$ volt, some 6000 such cells being operative, in series, in quite a small animal.

A highlight of this broadcast was a remarkable demonstration of the conversion of the regular electric oscillations from a fish into a melodious note, and a tape recording from a shoal of such electric fish oscillators was a strange orchestra indeed. This whole broadcast was absorbing. It was tense, informative, brilliantly executed, admirably produced, and a perfect example of how to produce an effective visual broadcast with the minimum of equipment. It was a veritable model of how two scientists with little other than their brilliant experimental ingenuity can easily excite us.

May 17 saw another fine "Eye on Research" broadcast, again with the stage held essentially by *one* scientist. Here Dr N. Kurti, F.R.S., of Oxford, illustrated his recent work at very low temperatures. His infectious enthusiasm and his obvious dynamic intense love of his subject irresistibly communicated itself to the listener. With vivid intensity he roused interest in a direct experiment he proceeded to carry out, trying to reach within one millionth of a degree of the absolute zero of temperature and he got very close to his objective. He took great pains to explain clearly what low-temperature research was after. It was not merely the chase after an unattainable absolute zero of temperature; on the contrary, it was essentially a determined effort to reduce to a minimum the disorder amongst the molecules of matter produced by thermal motion. This was elaborated with admirable animated diagrams. He literally opened up the eyes of his laymen viewers to the fascinating scientific possibilities which might be expected from a continual reduction in molecular and atomic disorder. His experimental demonstrations, difficult in fact to carry out, went off very smoothly. A delightful broadcast indeed.

On May 24 "Eye on Research" slipped back into its wicked old habit of using catchy titles, giving us a programme entitled *The Roar of the Crowd*. This had nothing to do with that other famous roar of the crowd, the Hampden roar at a Scottish Cup Final. It had nothing to do either with roaring or with crowds! It was a title that gave no hint whatsoever that what was to follow was a profoundly interesting film recording of brain studies. The programme was made at the Neurological Institute, Montreal, Canada, describing the work of Dr W. Penfield, O.M., F.R.S. Naturally it had to be film and not a live broadcast, but it was certainly one of the best science recordings we have seen on BBC and had very much the character of a live broadcast. To a large extent the broadcast was an interview of Dr Penfield, ably conducted by Lister Sinclair, who is unknown to us. There were, in addition, appreciable extracts from the general work of the Institute, including a filming of a brain operation, which was too theatrical and perhaps a little out of place, although its inclusion might well be justified.

Without any fuss at all Penfield showed us how brain electrical activity functions and carefully drew our attention to the relationship between clinical epilepsy and electrical discharges in the brain. One soon became absorbed by the cleverness of the manipulations and the subtleties of the conclusions drawn from simple but careful observations. Particularly remarkable was the way in which we were shown that local brain stimulation could actually recall specific memories, such as a definite tune.

Such work as this is undoubtedly on the verge of something very fundamental indeed for humanity. It has always seemed to your reviewer that the one single most important feature of brain activity which is basically responsible for the whole of human culture and achievement, is in fact memory. It is precisely only because of this mysterious ability to store and recall impressions that we are at all able to learn anything. Memory is indeed as great and as important a mystery almost as life itself, for without memory we might just as well still be a collection of undifferentiated cells, for all we could achieve.

To see a broadcast hinting that neurologists are at last beginning to get the thin end of the wedge into the prising open of some of the mystery of memory is indeed a memorable occasion. It is perhaps worth quoting that at the end of his broadcast Dr Penrose commented that "Research on the brain is far more important to man than research on outer space". There are many who would agree with this appraisal.

We sincerely hope that the BBC will long carry on with its chain of programmes on the work of distinguished scientists. There are, after all, over 600 Fellows of the Royal Society and if even only a quarter of these Fellows are engaged in researches suitable for a television broadcast, they will fill a weekly programme for three whole years to come. There is ample talent, maybe as much if not more, outside as inside the Royal Society, merely in this country alone. And when these are exhausted there are vast foreign reserves to tap. S. TOLANSKY

Russian Earth–Moon Film

Shooting of the film *Earth–Moon* has been completed at the Moscow Popular Science Film Studio. The film shows how man has opened up the longest road ever, from the Earth to the Moon, the first stepping-stone along which were the launchings of the three Soviet *Sputniks*.

Filmgoers will see the trajectory of the first Soviet space rocket which passes at a distance of some 6200 miles from the Moon to become the tenth planet of the solar system.

The film also shows how the invisible part of the Moon was photographed, as well as the operating principle of the television equipment installed on the third Soviet space rocket, and certain experiments in studying interplanetary flight conditions.

Earth–Moon also reflects the work done by American scientists in the conquest of space. It contains shots of the launching of a space rocket in the United States.

FAR AND NEAR

First Woman Dip. Tech.

The first woman to be awarded the Diploma in Technology was included in a recent list of awards issued by the National Council for Technological Awards.

She is 24-year-old Shirley P. Wallis, of 8 Vernon Close, West Kingsdown, Sevenoaks, Kent. Miss Wallis is doing basic research in the radio department of the Royal Aircraft Establishment, Farnborough, where she has been employed for the last five years. Miss Wallis was educated at Dartford Grammar School, where she gained her G.C.E., Advanced level in Pure Mathematics, Applied Mathematics and Physics. Joining the Ministry of Supply in November 1954, she was selected for a Ministry of Supply grant for the first Applied Physics sandwich course at the Northampton college of Advanced Technology, where she started in January 1956.

Miss Wallis received her diploma at the Northampton College of Advanced Technology, St. John Street, Clerkenwell, E.C.1 in February. It was presented by Sir Harold Roxbee Cox, the new chairman of the National Council for Technological Awards.

Contracts for Magnet Power Supply for Proton Synchrotron

The National Institute for Research in Nuclear Science has placed contracts for electrical equipment to supply power to the magnet of the 7000 million electron-volt proton synchrotron. The apparatus is being built for the Institute by the United Kingdom Atomic Energy Authority at the Rutherford High Energy Laboratory, Harwell. The British Brown-Boveri Co. Ltd have been awarded the contract for the convertor plant and the English Electric Co. Ltd the contract for the rotating machinery.

The purpose of this equipment is to supply accurately regulated pulses of power to the windings of the eight sections of the synchrotron's 7000-ton ring-shaped magnet; in this way the protons are kept in their path as they are accelerated. Thirty-five megajoules of energy (equivalent to the energy of a 100-ton locomotive moving at 60 m.p.h.) has to be converted, at a controlled rate, from stored energy in the flywheels to field energy in the magnet during the three-quarters of a second in which the protons are being accelerated; they must then be returned to the flywheels for about a second until the next pulse.

The rotating machinery consists principally of two large motor-alternator-flywheel sets mechanically coupled together. The power fed in by the motors to keep the process going is 10,000 h.p. The converter plant includes excitrons, which are large mercury vapour switches, timing and control equipment, and transformers.

Modernist Burglars

Burglars cast an anti-social slant on the doctrine of self-help. Yet, although seldom concerned with bettering themselves, they are frequently among the first to improve their equipment.

A recent attempt to break into the premises of a Hatton Garden jeweller is illustrative of the deviously progressive nature of the modern burglar. After the raid, an inspection of the burglars' equipment brought to light a new type of oxy-acetylene cutting torch that had been on sale little more than a fortnight. The torch, which is manufactured by British Industrial Gases Ltd, incorporates the very latest refinements.

Fortunately, in this case, the raiders were disturbed in time, but it is interesting to record that one of the very first users of an oxy-acetylene blowpipe was a burglar who cut open a Post Office safe. This caused alarm in the business and banking world, the public's initial reaction to the wonders of oxygen-engineering being a vigorous demand that it should be prohibited by law.

GIANT BRAKE LINERS

National Coal Board for mine-shaft lifting gear, are 13 ft. 5 in. long and 19 in. wide. The 1-in.-thick sections of woven asbestos and cotton are bonded with "Redux" resin adhesive to the metal; four sections are required to cover the circumference of the braking wheel mechanism

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U.S. NAVY RADIO TELESCOPE UNDER CONSTRUCTION

Foundations for the World's largest radio telescope are laid in the mountains of West Virginia near Sugar Grove. To be named the U.S. Naval Radio Research Station, it is scheduled for completion in 1962. Ten thousand cubic yards of reinforced concrete are being poured to make the base for the 20,000-ton, 600-ft.-diameter telescope. The instrument at the upper right is a 60-ft. radio telescope to be used by the Naval Research Laboratory for seeking out sources of electrical noise which interfere with radio-wave reception in large sensitive telescopes.

An African Institute of Tropical Meteorology

An Institute of Tropical Meteorology serving all countries in tropical Africa is to be set up in Nairobi, Kenya, reports UNESCO. The Institute will be financed by funds from the Munitalp Foundation, a non-profit organisation in Kenya which carries out scientific research.

The announcement was made at a Symposium on Tropical Meteorology in Africa, held recently in Nairobi under the auspices of the Munitalp Foundation and the World Meteorological Organisation, in which scientists from twenty-six countries took part.

The task of the new Institute will be to collect and distribute all available knowledge on tropical meteorology and related subjects.

The Institute will co-operate closely with the East African Meteorological Department, the East African Agricultural and Forestry Research Organisation, and with the World Meteorological Organisation.

Pacific Telephone Cable

The first transpacific cable, which will be the second link in the scheme to link the whole of the Commonwealth by telephone, is beginning to take very definite shape.

It is only just over a year ago that Commonwealth Finance Ministers gave their blessing in principle to a proposal to construct a round-the-world cable providing for telephony, telegraphy, telex, and picture telegraphy. Only a few weeks ago representatives of Australia, Canada, New Zealand, and the United Kingdom met at Sydney to reach positive agreement. It has been a really splendid example of four countries within the Commonwealth family working together.

If this report is approved by all four Governments then we shall have taken a big stride towards the Pacific link in this "round-the-world" cable. Mr Bevins, the Postmaster-General said that he certainly hoped that this Pacific link would anticipate the centenary in 1966 of the first successful transatlantic telegraph cable.

Inert Gas Production

In connexion with certain difficulties encountered in the handling of fuel gases, the Dryer and Gas Plant Division of Birlec Limited is designing an inert gas generator with a capacity of 200,000 cu. ft./hr. Fuel gases of all kinds can form explosive mixtures with air. The pipes, tanks, gas-holders, and process vessels used in the manufacture or handling of fuel gases need to be emptied from time to time. Before air can be let in, fuel gas must be removed. This needs a suitable inert purge gas. For example, after a catalytic refining process has been carried out for a time, the catalyst promoting the process needs cleaning. Before this can be done, fuel must be purged out of the plant. When the plant is again ready to be put on stream, the system must be purged with inert gas to ensure the removal of all traces of oxygen in each case, to avoid the possibility of explosion.

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PUBLIC MEETINGS

DR. LINUS PAULING—on "Why the World Must Achieve Total Disarmament"—July 17, 7.30 p.m., St. Pancras Town Hall; adm. 2*s*., or from the British Peace Committee, 81 City Road, E.C.1 (CLE. 0383).

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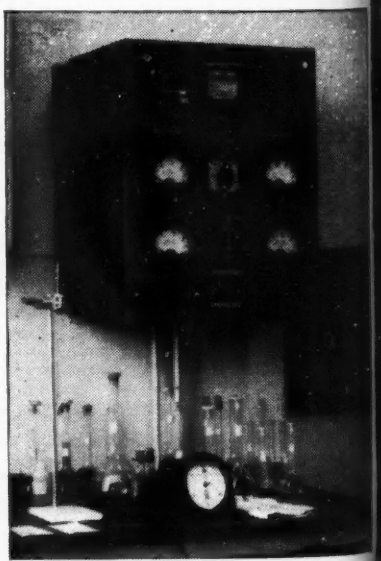

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